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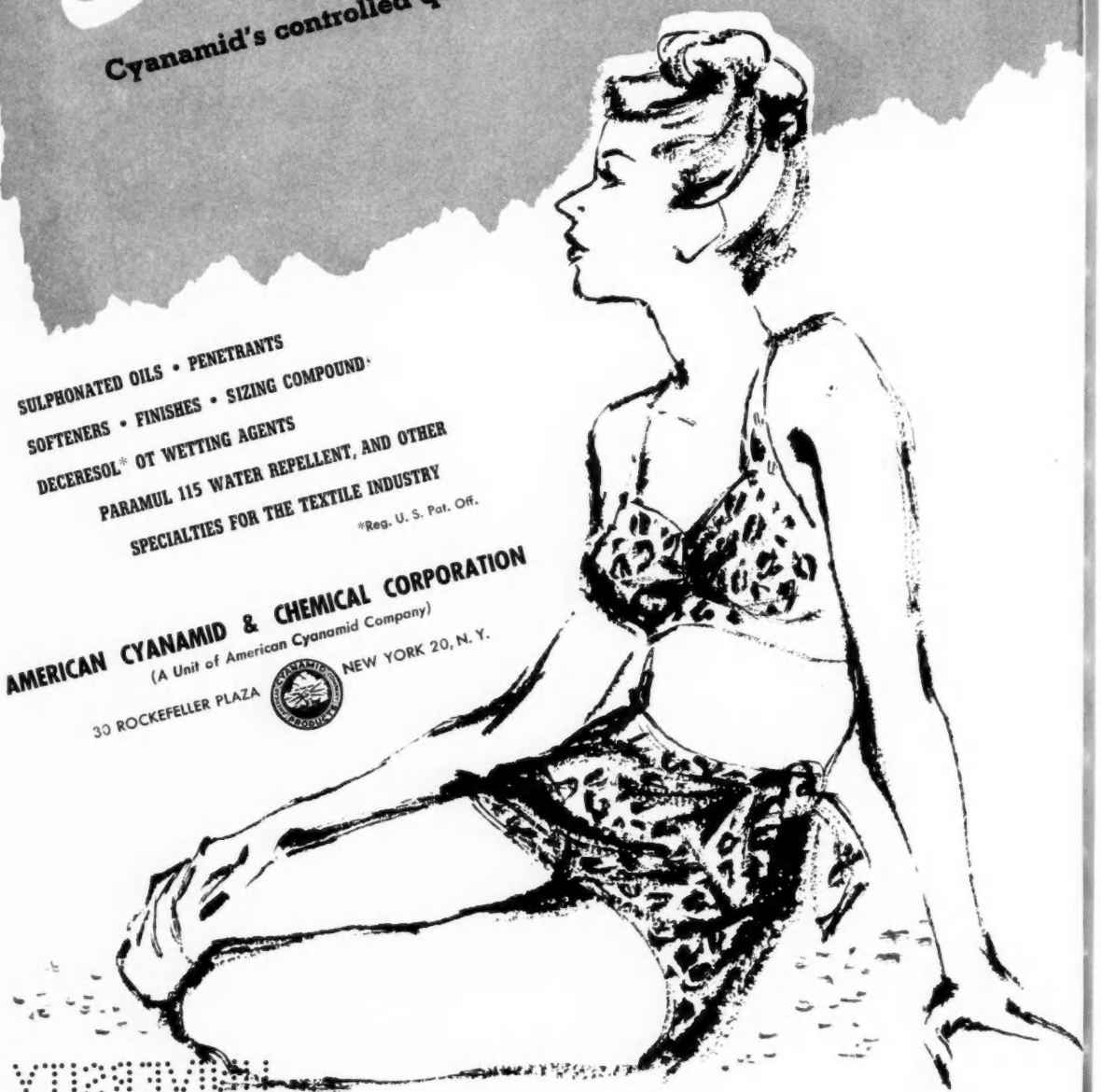

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(Additional applications appear on page P281.)

THE STANDARD FADING LAMP

at the National Bureau of Standards and Means of Calibrating Other Lamps in Terms of It*

DR. HERBERT F. LAUNER
National Bureau of Standards

An Extract

THE results of 2½ years of research were described.

Pointing out that it has been generally appreciated for a long time that arc lamps vary greatly in their fading of dyed textiles, from place to place and time to time, Dr. Launer submitted results of a survey conducted by the National Bureau of Standards using Victoria Blue B on a cotton rag paper. The survey showed quantitatively how great the variations actually were, and how great is the need of a method of calibration. These results are given in Letter Circular 785, issued on March 31, 1945, by the National Bureau of Standards, copies of which are available.

Standard Fading Lamp—The first step in such a calibration was conceived of as being a unit in which fading is reproducible at all times. This "Standard Lamp" has been developed at the Bureau. It is a carbon arc housed in a special room. The temperature and relative humidity of the air in the room, the line voltage, and arc current are automatically controlled and their values recorded. The radiant output of the arc throughout the visible and ultraviolet regions of the spectrum is recorded by an instrument specially built for the purpose. A 10-years' supply of carbon electrodes manufactured for the lamp from one batch of raw materials to meet very close tolerances is on hand. The lamp has been adjusted to produce fading at a rate equal to that of the average of the lamps included in the survey.

Calibration—In order to calibrate other arcs in terms of the reference standard arc, a suitable medium had to be found. The smoothness of paper was immediately recognized as being a valuable aid in the visual judging of fading, which type of judging is, of course, highly desirable for its simplicity.

A dyed paper, however, may not, and usually does not, act at all like a dyed textile when exposed in fading lamps. Accordingly, considerable experiment was necessary before it was finally found that Benzoazurine G (Colour Index 502) on purified sulfite paper, responded to changes in relative humidity and type and make of arc lamp, in the same manner as most textiles simultaneously exposed. This characteristic obtained also in the Survey paper, although the Victoria Blue gave a mottled endpoint, better for instrumental than visual judging.

It was also shown that the paper dyed with C. I. 502 called Calibration Paper A could be used with surprisingly good results in "calibrating sunshine" for some dyeings, but failed miserably for others. This can probably be expected of any dyeing, and the results were presented only because of the widespread interest in this phase of the problem.

Dr. Launer then showed, using this paper, how several commercial arc lamps varied from day to day, and what relative constancy of performance had been achieved in the Standard Arc. Whereas the difference between extremes for a widely used commercial arc was 37 per cent over the short period of two weeks, that in the Standard Arc was 6 per cent.

It was pointed out that other desirable attributes of a calibration paper, such as good storage stability and easy visual distinctness of the endpoint, were among those of Calibration Paper A. A slide was shown comparing it with some other proposed calibration media. The differences in color (corresponding to what could be shown in black and white projection) for 16, 18, 20 and 22 hours of exposure made it appear to be a simple matter to judge the fading of a strip of Paper A placed in any fading unit for the purpose of calibration.

Slides were shown of the Standard Arc and auxiliary equipment, including a newly developed automatic recording filter spectro-radiometer for studying spectral distribution of variable light sources.

Calibration Paper A along with a strip exposed in the Standard Arc for 16, 18, 20, and 22 "Standard Fading Hours" may be obtained from the National Bureau of Standards, Washington 25, D. C.

* Presented at meeting, Philadelphia Section, April 20, 1945.

Some Variables in WEATHERING TESTS of Textile Fabrics*

STANLEY BACKER and RALPH HARWOOD
Captain, Q.M.C. *Technologist*
Assistant to O.I.C.,
Research and Development Division Philadelphia Quartermaster Depot

INTRODUCTION

THE discussion of weather testing variables contained herein is based upon a formal report by Ralph Harwood covering the results of a series of studies carried on by the Research and Development Division of the Philadelphia Quartermaster Depot, as a formal project under the direction of the Military Planning Division of the Office of the Quartermaster General. Every manufacturer of textiles for the Army is familiar with the phrase, "shall exhibit good fastness to weather, samples shall be exposed for 30 days." As quoted, the weather test was often questioned as a proper means of evaluating color fastness; the variability of such a test has been recognized for some time both by the manufacturer and by the government laboratories. No doubt some manufacturers have upon use of a more fugitive dyestuff in their depot deliveries of government fabrics, prayed for cloudy weather during the ensuing 30 days. In the case of some manufacturers, submittal of a fabric sample, rejected for poor weather fastness during the summer, for a second weathering test during the winter, has brought the puzzling depot comment that improvement is noted in the manufacturers process with regard to fastness to weathering.

The textile industry has turned to manufacturers of electrical devices for their assistance in this problem, in the form of fading and weathering equipment, essentially of the carbon arc variety. Chemical manufacturers have, by continued calibration and control, found it possible to use these devices as a definite source of information concerning dyestuff fastness characteristics; textile manufacturers as well, utilize the carbon arc lamps for control purposes. The variability of such apparatus has long been recognized; a series of articles has been published covering the factors influencing carbon arc performance.

With such a background it is felt there are two steps which may be taken to put the results of carbon arc fading on more of an absolute basis: (1) elimination, or control of instrument variables; (2) acceptance of instrument variables while at the same time superimposing on the instrument results, quantitative factors of calibration. It is believed that each of these steps will be covered in this symposium and a reasonable conclusion reached as to the most practical method for the industry and governmental procuring agencies.

Over and above the criticism of carbon arc lamps as not being consistent within themselves, is the complaint that they are not consistent with the results obtained from free exposures to sunlight, i. e., weathering tests. Without doubt there are cases where dyed materials will not fade under the carbon arc lamp but will fade in a natural weathering test and vice versa. Getting back to the inconsistencies of weather noted above, the cause for disagreement of carbon arc tests with natural weathering tests often lies in the weathering test itself.

In order to ascertain the extent of variables in weathering testing and their effect upon the fading of olive drab serges delivered to the Philadelphia Quartermaster Depot, the study reported on at this time was initiated early in 1943. The project provided for a comparison of weather exposures made under various conditions of geographical locations and climates, as well as on the available commercial fading equipment in the depot laboratory.

PLAN OF TEST

Outdoor Exposures

Cloth submitted by ten (10) contractors during 1943 was exposed in nineteen (19) different locations throughout the United States as indicated in Table I and Chart I. The locations selected for the study included the northern and southern extremes of the Atlantic Coastline, the Pacific Coastline, the Middle West, the Rocky Mountain and Appalachian regions, and the mid-eastern and mid-western sections of the United States. Swatches measuring 8" x 10" were exposed in an uncovered position on 45° angle panels facing toward the south. The months of June, July, August and September were the dates for exposures, with tests starting at the beginning of each month and ending in successive 10, 20 and 30-day periods. Thus at the end of the outdoor exposure period there were available samples of ten (10) contractors exposed in nineteen (19) locations throughout the United States for periods of 10, 20 and 30 days during the interval between June to September 1943. Samples were evaluated as received, as well as after washing.

Instrument Exposures

Three conventional types of accelerated fading units were used for instrument exposures of the samples listed above: (1) the Atlas Fadeometer, Type FDA-R, consisting of an enclosed ultra-violet carbon arc similar in radiation characteristics to natural sunlight; (2) the Atlas Twin Arc Weatherometer, Type DL-TS, which combines the basic principles of operation of the FDA-R Fadeometer with the addition of a fine spray upon the samples during exposure; and (3) the National Type XV Accelerated Fading Unit consisting of a single, operating, carbon arc with Corex D Filters. Successive samples from each manufacturer were exposed for periods of 40, 80, 120 and 160 hours in each of the machines listed.

Evaluation of Exposures

It would appear that considerable information was available from the tests outlined above, for when the dyeing formulas for the samples tested were combined with the meteorological conditions observed in the nineteen (19) localities including hours of sunshine, total precipitation, temperature, relative humidity, latitude, altitude, population, type of locality, etc., there was indeed a sizeable amount of data. Add to this the evaluation of 2400 exposures and the result is a complex problem, the answer to which should provide definite information as to the variables in which we are most interested. It was recommended early in the project that visual evaluation of such a large number of samples, while being the most direct and quickest to obtain, would be most difficult to interpret or reproduce. Accordingly a method was sought which would provide the measure of fading in a single absolute figure which could be computed and reduced by proper statistical methods to afford investigation of any or all of the variables in the test procedure. There was available in the depot laboratory a Multipurpose Reflectometer, designed by Mr.

* Presented at meeting, Philadelphia Section, April 20, 1945.

TABLE NO. 1

Average Meteorological Conditions Observed in Nineteen Localities for 10, 20, and 30 Day Periods for the Summer of 1943.

Period of Exposure	Locality	Average Hours of Sunshine	Average total Precipitation for Each Period	Average (°F.) Temperature	Average Per Cent Rel. Humidity	Average Per Cent Dirt	Latitude	Altitude	Population (1940 Census)	Composition of Dirt	Type of Locality
10 Days	Minneapolis	92.6	1.45	67.7	62.0	0.04	44° 58′	812	492,370	medium, dark, sooty	light industrial
	Lowell	70.9	0.38	69.4	70.6	0.03	42° 37′	101	101,389	coarse, sandy, grey	light industrial
	Milwaukee	86.5	0.24	66.3	73.5	0.03	43° 2′	636	587,472	light coarse particles	industrial
	Memphis	98.6	1.45	80.5	71.6	0.05	35° 10′	273	292,942	light coarse particles	light industrial
	St. Louis	87.6	1.29	77.0	64.9	0.04	38° 38′	455	816,048	heavy, dark, sooty	heavy industrial
	Los Angeles	109.9	0.0	68.4	66.1	0.03	34° 3′	338	1,504,277	coarse, sandy, grey	light industrial
	Amarillo	96.9	1.38	76.3	62.0	0.04	35° 8′	3,683	51,686	light, granular	rural, semi-industrial
	Philadelphia	67.0	1.03	75.4	65.6	0.12	38° 46′	708	386,972	heavy, dark, sooty	heavy industrial
	Hialeah	86.5	0.82	80.5	78.5	0.03	39° 55′	9	1,931,334	light, sandy	rural-open
	Indianapolis	94.2	1.34	74.8	77.6	0.08	25° 44′	20	3,958	dark, sooty	exposed in rural area
	Ames	77.0	2.32	72.8	79.4	0.06	42° 2′	1,000	12,555	light, crystalline	rural
	New Orleans	89.5	1.03	82.2	75.6	0.04	29° 57′	5	494,537	sandy, granular	light industrial
	Charlotte	90.5	2.21	79.0	73.2	0.05	35° 15′	721	100,899	light, coarse particles	light industrial
	Portland	97.2	0.37	65.9	69.2	0.05	45° 30′	174	305,394	light, coarse particles	industrial
	Ogden	118.0	0.41	68.9	43.3	0.02	41° 20′	4,296	43,688	very fine dust	exposed in rural area
	Pittsburgh	56.6	0.98	74.1	78.2	0.02	40° 27′	744	671,659	heavy, dark, sooty	heavy industrial
	Salem	67.0	1.03	75.4	65.6	0.05	39° 39′	9	8,618	coarse, light, sandy	rural
	Lisbon Falls	87.0	1.15	63.9	77.1	0.04	44° 0′	200	2,500	medium, grey, coarse	very light industrial
	San Francisco	95.8	0.03	58.0	80.7	0.06	37° 46′	15	634.536	medium, sooty	light industrial
20 Days	Minneapolis	200.2	2.48	67.7	62.0	0.10					
	Lowell	160.1	0.99	69.8	67.9	0.07					
	Milwaukee	175.3	0.76	66.8	72.5	0.05					
	Memphis	206.6	1.73	80.5	69.7	0.03					
	St. Louis	182.7	2.04	76.7	64.1	0.07					
	Los Angeles	222.8	0.0	68.7	63.3	0.08					
	Amarillo	206.2	1.93	76.4	62.0	0.10					
	Philadelphia	157.0	1.73	74.4	65.2	0.21					
	Hialeah	177.8	2.53	80.8	78.5	0.07					
	Indianapolis	196.2	2.46	74.1	76.2	0.08					
	Ames	166.0	4.69	73.9	76.9	0.06					
	New Orleans	178.9	4.99	81.7	76.2	0.04					
	Charlotte	187.3	3.94	78.3	73.3	0.05					
	Portland	179.2	0.87	65.8	70.3	0.05					
	Ogden	228.0	0.66	69.7	42.1	0.02					
	Pittsburgh	122.0	2.29	72.9	78.3	0.02					
	Salem	157.0	1.73	74.4	65.2	0.05					
	Lisbon Falls	187.6	1.75	63.9	77.5	0.04					
	San Francisco	197.5	0.03	59.0	77.7	0.06					
30 Days	Minneapolis	305.4	3.16	68.8	62.0	0.09					
	Lowell	240.8	2.02	69.8	69.0	0.09					
	Milwaukee	264.5	1.64	67.0	72.7	0.08					
	Memphis	298.7	2.04	79.9	69.5	0.04					
	St. Louis	287.8	2.86	76.9	62.3	0.11					
	Los Angeles	330.4	0.0	69.7	61.7	0.15					
	Amarillo	286.8	2.63	75.8	62.0	0.13					
	Philadelphia	244.5	2.58	74.0	64.3	0.19					
	Hialeah	245.6	5.71	80.4	79.3	0.07					
	Indianapolis	296.1	2.83	73.8	67.5	0.16					
	Ames	301.3	5.91	70.7	73.3	0.19					
	New Orleans	243.6	4.69	80.7	77.3	0.05					
	Charlotte	290.9	5.22	77.7	73.7	0.12					
	Portland	295.6	1.23	65.9	70.3	0.09					
	Ogden	354.0	0.68	70.8	41.0	0.08					
	Pittsburgh	186.3	3.63	72.9	71.0	0.27					
	Salem	244.5	2.58	74.0	64.3	0.14					
	Lisbon Falls	284.3	2.78	64.1	77.5	0.09					
	San Francisco	313.4	0.05	59.9	76.5	0.12					

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Source: Wool, Serge, Dark O.D., 18 ounces, Weather and Light Fastness Project, F.Q.M.D.
U. S. Weather Bureau
Rand McNally's Commercial Atlas

Hunter of the Bureau of Standards, so the first resort to other measurements of fading was had to this instrument. However, before entering upon any extensive program of measurement and calculation, it was deemed advisable to relate the readings of such an instrument with other more exacting methods of measurement, and finally with visual grading itself.

The relationship between the readings obtained on the Hunter Instrument and on other spectrophotometric instruments is shown in Charts II and III. By setting up arbitrarily assigned numbers from 1 to 10, which range from the least faded to the most faded sample, respectively, visual grading was made possible for a selected number of samples. These same samples measured on the Hunter Instrument provided the relationship shown in Chart IV. It is readily seen that a sample which has been severely faded is so designated by the Hunter Instrument as well as by the GE Spectrophotometer, the Snow Duplex Spectrophotometer, and by the professional color matcher at the depot laboratory. On this basis it was considered safe to continue the analysis of the fading exposures by means of the Hunter Instrument.

Outdoor Fading Exposure Data

Presentation of 2400 values of relative fading would indeed be cumbersome, if not impractical for extensive analysis, and so it was deemed advisable to reduce the unwieldy number of exposures to more condensed tables and charts to permit observation of specific trends. It is felt that entry into a discussion of the test results and conclusions drawn therefrom would be most easily affected by presentation of specific questions and answers as follows:

1. How does fading in different locations vary from month to month? In order to provide an answer to this question the fading noted in each locality and at each period was averaged for the ten base fabrics to give the values plotted in Chart V. The picture presented in such data gives the observer opportunity to evaluate the reproducibility of fading in the localities studied both from the standpoint of location and time. It is realized that changes in the results reported may be expected,

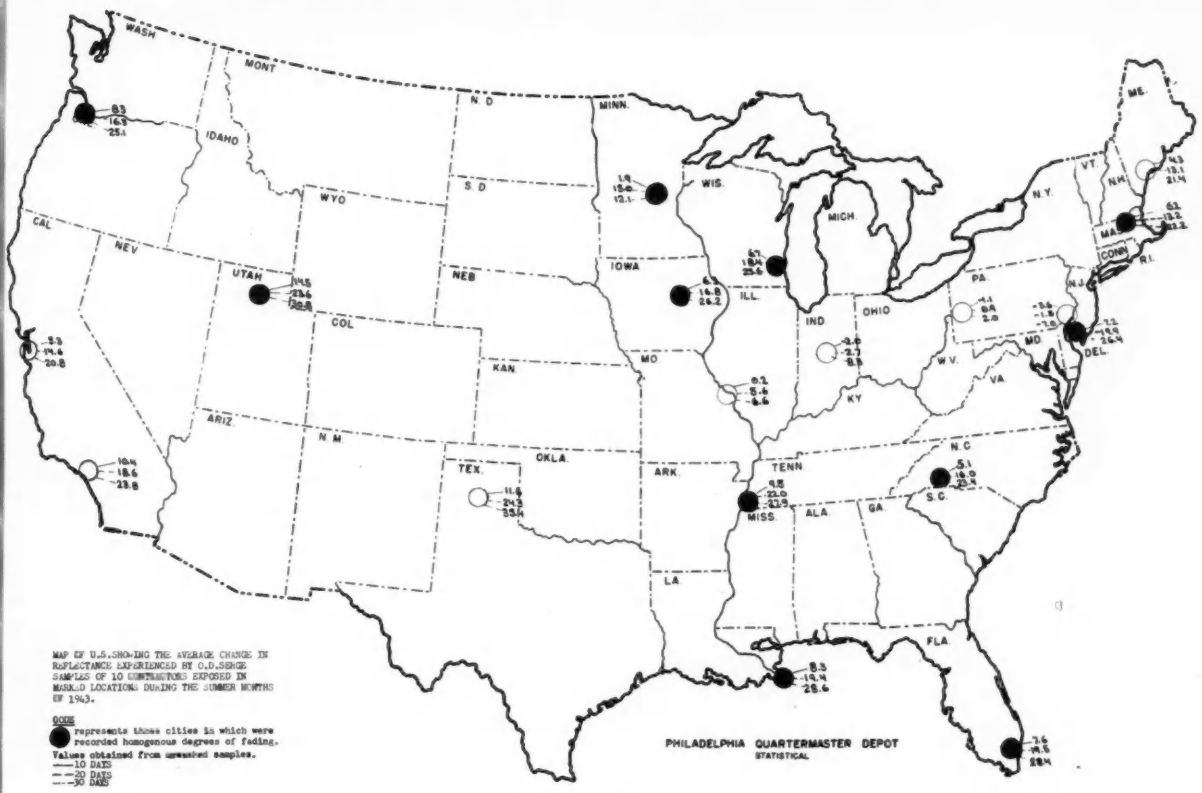


Chart No. 1

were the exposures to be repeated in the same cities but at slightly different locations during the coming summer months. It is reasonable however to assume that locations enjoying relatively uniform periods of weather during a given year will encounter reoccurrence of such weather from year to year; exceptions to the statement may be found in individual instances but tend to average out over the country taken as a whole. Certain locations on the other hand are noted for their highly variable weather conditions. Cities such as Amarillo, Texas; Hialeah, Florida; New Orleans, Louisiana; and Ogden, Utah, give evidence of uniform fading throughout the summer months of 1943 while Lisbon Falls, Maine; Pittsburgh, Pennsylvania; Indianapolis, Indiana; Philadelphia, Pennsylvania; and Memphis, Tennessee show poor reproducibility. Again there appears to be no evidence of excessive fading occurring in one month against the other. June fading in Indianapolis for example seems more severe than July, August and September fading for similar length periods; in Portland, Oregon, June fading appears to be the least severe.

2. *How does fading vary from one locality to the other within the United States?* The data of Chart V has been consolidated to permit more ready comparison of the average fading incurred from one locality to the other as shown in Chart VI. Here is plotted the average fading incurred in each locality as measured on both the washed and unwashed swatches. As was expected the major portion of the samples gained in apparent reflectance upon washing; the exceptions to this expectation, occurring in the case of specimens exposed at Amarillo, Ogden, Ames, and Los Angeles, may be attributed to the presence in the majority of these locations of a grey, sandy, crystalline dust rather than a dark sooty dirt found in the more heavily industralized areas. The graphs of average fading for 10, 20 and 30 days exposure in the 19 locations show definite groupings of the highly industrialized cities where rate of fading is at a minimum. Although Indianapolis and San Francisco were not heavily industrialized, nevertheless there was deposited on samples exposed in these cities a medium and heavy soot which added considerably to the apparent resistance to fading of the samples.

A definite factor leading to maximum fading in the locations studied was simply the average number of sun hours striking the samples. Amarillo, Ogden and Memphis consistently showing a high degree of fading over the 10, 20, and 30-day periods of exposures, were among those cities credited with the higher average hours of sunlight—in each of these cities there was no heavy sooty deposit on the fabric to detract from the excessive sun exposures encountered. Ogden which recorded the highest number of sun hours was also reported to have had the lowest humidity of the 19 cities, a factor which was believed to reduce to some extent the degree of fading incurred under the prolonged sun exposure in this city. New Orleans, on the other hand, with a moderate number of sun hours but with the highest recorded temperature and the third highest humidity over the 30-day period provided the third highest average fading. Similarly Hialeah, Florida reports a moderate number of sun hours accompanied by extremely high temperatures and humidities with resultant high rates of fading. San Francisco with the second highest number of sun hours over the 30-day period showed comparatively little fading, reporting at the same time the lowest average temperature of the 19 locations, a high R.H. and a moderate amount of medium soot precipitated on the fabrics. Finally Los Angeles with the highest number of sun hours over the 30-day periods

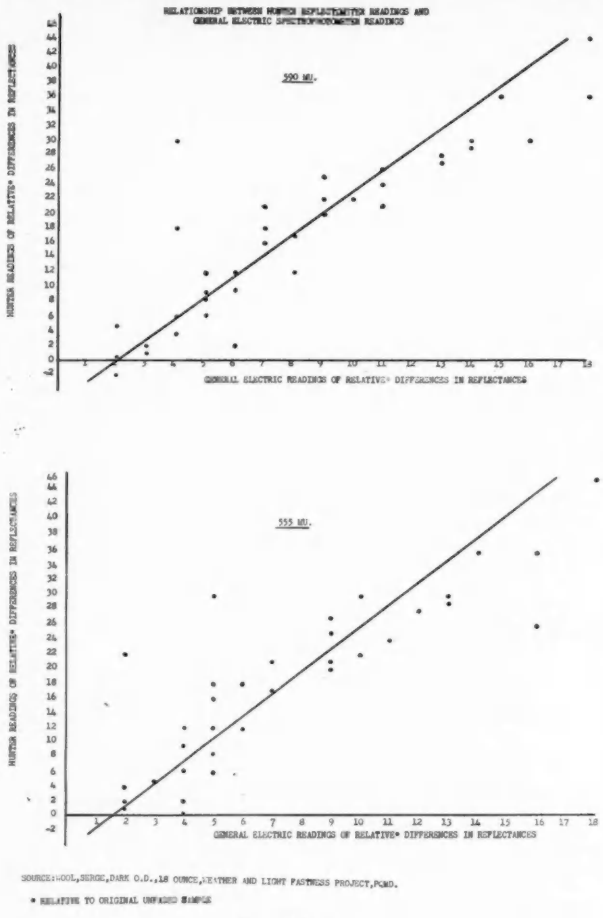

590 MU.
555 MU.
GENERAL ELECTRIC READINGS OF RELATIVE* DIFFERENCES IN REFLECTANCES
HUNTER READINGS OF RELATIVE* DIFFERENCES IN REFLECTANCES
SOURCE:WOOL,SERGE,DARK O.D.,18 OUNCE,WEATHER AND LIGHT FASTNESS PROJECT,P.M.D.
* RELATIVE TO ORIGINAL UNFADED SAMPLE

Chart No. 2

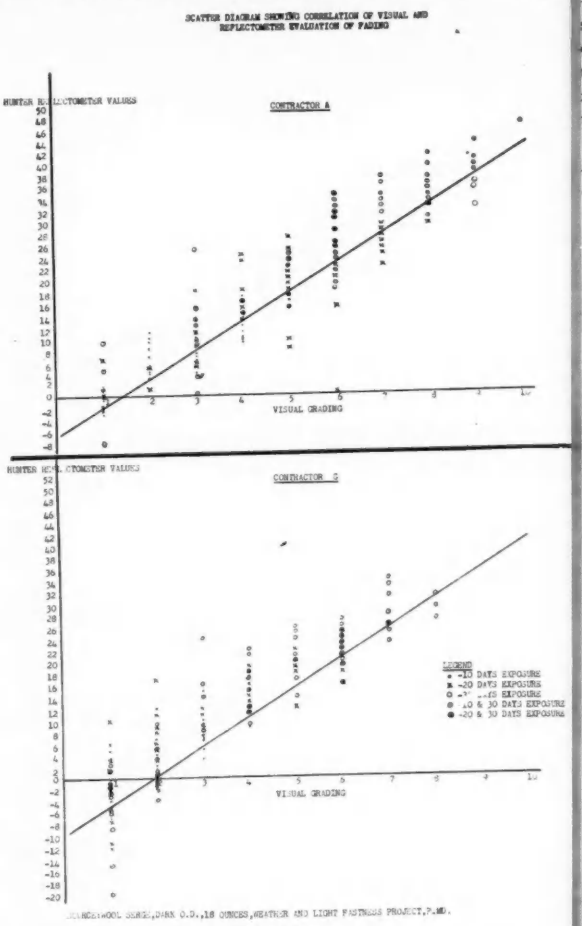


Chart No. 4

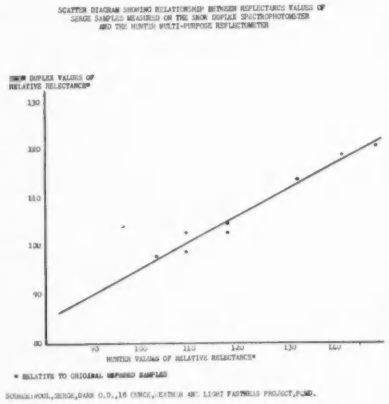


Chart No. 3

recorded no rainfall during the entire exposure, the sixth lowest temperature, and the lowest humidity of the 19 locations with an intermediate rate of fading among those shown in Chart VI. Minneapolis is similar to Los Angeles in this respect with a high number of recorded sun hours accompanied by quite low temperatures and humidities, and medium dark sooty deposits, resulting in low fading values over the exposure periods.

3. *What are the variables which affect fading of serge fabrics most upon exposure* (1) Sun hours for the most part—length of exposure and its effect on fading is seen in Charts V and VI where the changes in reflectance progress with the length of exposure from 10 to 20 to 30 days. Within each calendar period of exposure the difference in sun hours at each location has pronounced affect upon rate of fading; in all instances of high rate of fading cited above there has been a causative high number of sun hours recorded in the location cited. Maximum sun hours alone however did not provide maximum fading when accompanied by low average humidities and temperatures during the exposure periods. Harvey[3] provides an extensive summary of the effects of these factors and quotes Gooding[1] who in emphasizing the importance of humidity in the fading process, cites a case where the amount of fading on similar samples at 90 per cent R.H. was three times as gre as that produced at 30 per cent R.H. Al cited was the report of Barker and Hin to the effect that more severe fading w incurred in England because of the grea humidity there than in the tropics. App in 1928 and Cady[7] in 1931 both ackno edged the effect of temperature on fadi Harvey[3] Gooding[1] and Cunliffe[6] quote i stances of increased fading at higher te peratures. The data submitted in conn tion with this study is in agreement, in far as can be ascertained in the cases ferred to above, with the finding of p vious workers, to the effect that tempe ture and humidity have a direct relatio ship to rate of fading of the textile dy stuffs studied at this time. It must pointed out that any attempt to establi a prediction formula for fading bas upon the data submitted herein would unjustified in view of the limited exte of control possible during the experime Then again were such a formula est lished, it would be limited of necessity, the dyestuffs included in the ten basic fa rics of the experiment. Finally, it may

stated that no relationship was found to exist between latitude and altitude of location and the resultant fading; if such a relationship does exist the conditions of the experiment do not show it.

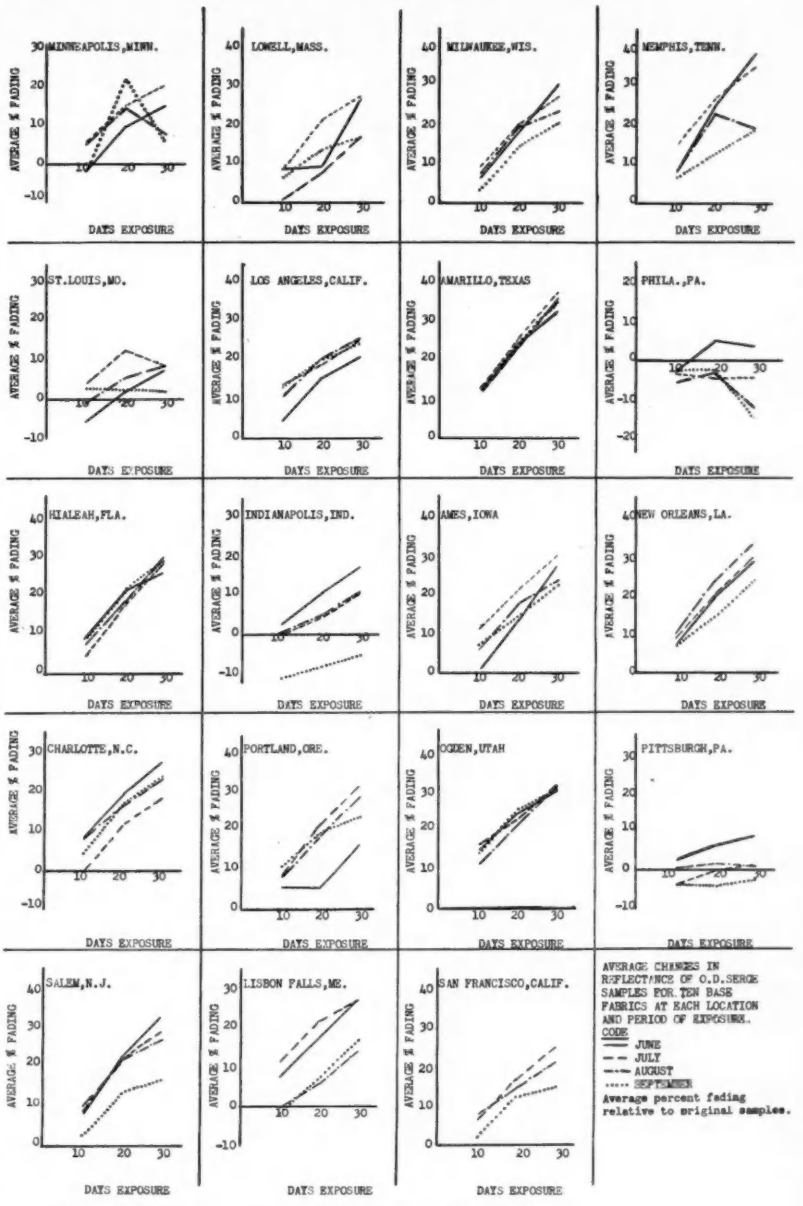
Question No. 4—What is average fading during the summer months throughout the United States?

In providing a value for average fading for 10, 20, and 30-day periods throughout the summer months, it was found feasible to omit the fading measurements obtained at those locations which vary considerably from the majority of the locations because of factors of sun-hours, temperature, relative humidity or dirt. The elimination of such irregular values was performed by use of the analysis of variance technique wherein the disagreement between the average fading of each location was evaluated for its significance in light of the variation incurred in fading from month to month. A separate process of elimination was applied to the fabrics when measured both in the washed and unwashed state. On the strength of such a computation the locations listed below were taken as the basis for computations of average fading during the summer months as well as the average number of sun-hours.

HOMOGENEOUS LOCALITIES

Unwashed	*Washed*
Lowell	Lowell
Milwaukee	Milwaukee
Memphis	Memphis
Los Angeles	Hialeah
Hialeah	Ames
Ames	New Orleans
New Orleans	Charlotte
Charlotte	Portland
Portland	Ogden
Salem	Salem
Lisbon Falls	

Computations based on the locations listed were made for washed and unwashed samples and provided the following figures of average per cent fading and average number of sun-hours for exposure during the summer months of 1943.



SOURCE:WOOL,SERGE DARK O.D.,18 OUNCE,WEATHER AND LIGHT FASTNESS PROJECT,PQMD.

Chart No. 5

Average Percentage Fading and Average Number of Sun Hours of Exposure in Homogeneous Localities

Designation	*10 Days*	*20 Days*	*30 Days*
Average number of sun hours (unwashed samples)	87.3	181.7	276.4
Average number of sun hours (washed samples)	88.2	181.6	278.0
Average percentage change in reflectance (unwashed samples)	7.2	17.9	25.3
Average percentage change in reflectance (washed samples)	8.1	20.7	26.6

The figures listed in this Table have been used as the basis of further comparisons between weather exposures and exposures carried out in the accelerated fading units. It must be recognized that the values apply only to the fabrics and dyestuffs studied in this experiment.

Question No. 5—How do the exposures in accelerated fading units compare to the actual weather exposures?

There is presented in Chart VII the results of fading lamp exposures of the ten (10) contractor's samples exposed for periods of 40, 80, 120, and 160 hours. Using the values of average number of sun-hours of weather exposure for the samples in homogeneous locations, the average fading for 10, 20 and 30-day periods of outdoor exposure has been plotted over the same chart (VII), thus permitting an over-all comparison on an hourly basis

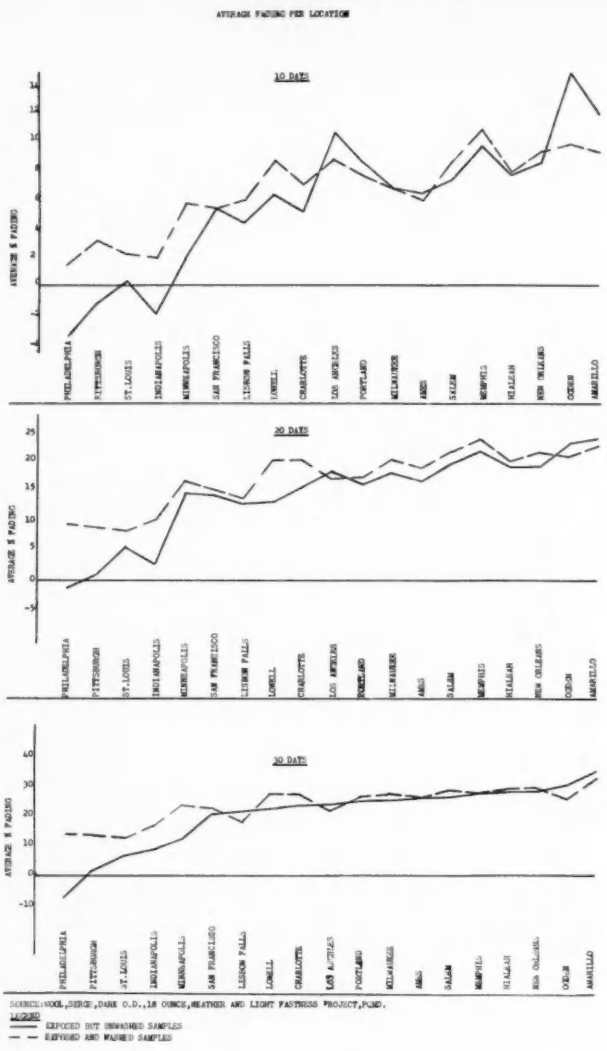


Chart No. 6

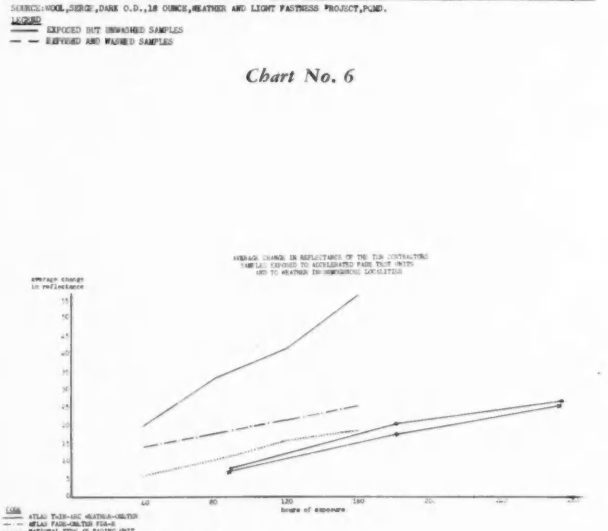

AVERAGE CHANGE IN REFLECTANCE OF THE TEN CONTRACTORS' SAMPLES EXPOSED TO ACCELERATED FADE TEST UNITS AND TO WEATHER IN HOMOGENEOUS LOCALITIES
Average change in reflectance
hours of exposure
LOSS
ATLAS FADE-OMETER
NATIONAL TYPE AT FADING UNIT
WEATHER EXPOSURES (HOMOGENEOUS UNWASHED LOCALITIES)
WEATHER EXPOSURES (HOMOGENEOUS WASHED LOCALITIES)
SOURCE: WOOL, SERGE, DARK O.D., 18 OUNCE, WEATHER AND LIGHT FASTNESS PROJECT, P.M.D.

Chart No. 7

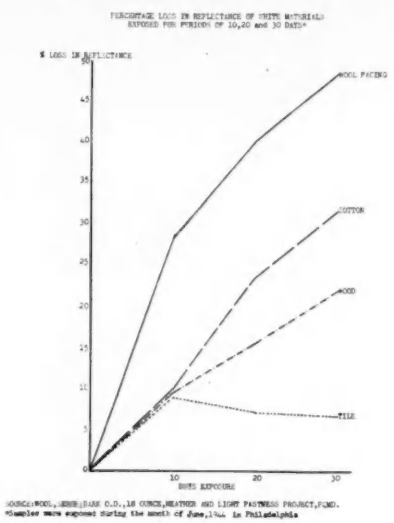

PERCENTAGE LOSS IN REFLECTANCE OF WHITE MATERIALS EXPOSED FOR PERIODS OF 10,20 and 30 DAYS*
% LOSS IN REFLECTANCE
WOOL FADING
COTTON
WOOD
TILE
HOURS EXPOSURE
SOURCE: WOOL, SERGE, DARK O.D., 18 OUNCE, WEATHER AND LIGHT FASTNESS PROJECT, P.M.D.
*Samples were exposed during the month of June, 1944 in Philadelphia

Chart No. 8

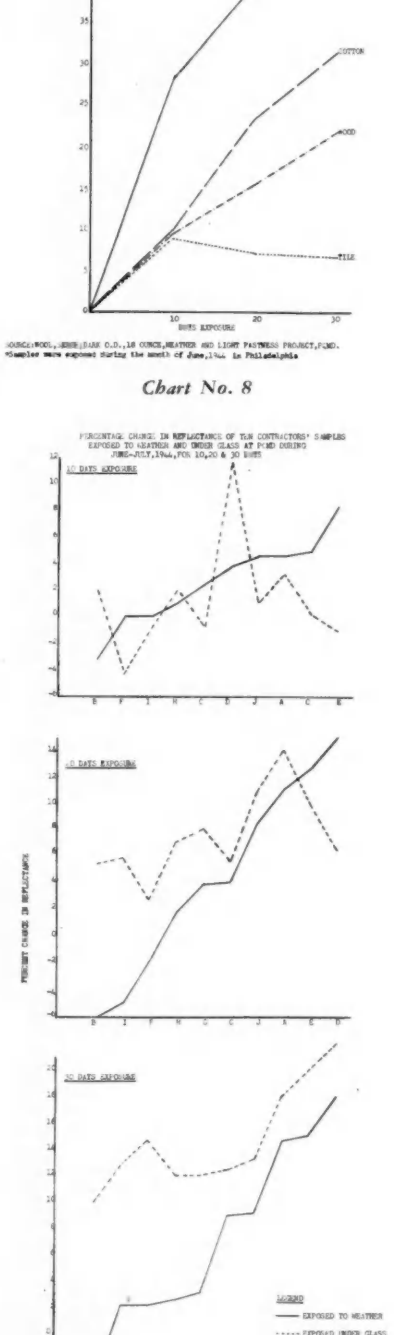

PERCENTAGE CHANGE IN REFLECTANCE OF TEN CONTRACTORS' SAMPLES EXPOSED TO WEATHER AND UNDER GLASS AT P.M.D. DURING JUNE-JULY, 1944, FOR 10, 20 & 30 DAYS
10 DAYS EXPOSURE
20 DAYS EXPOSURE
30 DAYS EXPOSURE
PERCENT CHANGE IN REFLECTANCE
SAMPLE NUMBER
LEGEND
EXPOSED TO WEATHER
EXPOSED UNDER GLASS
SOURCE: WOOL, SERGE, DARK O.D., 18 OUNCE, WEATHER AND LIGHT FASTNESS PROJECT, P.M.D.

Chart No. 9

of natural and artificial fading. Dividing the average fading for each period by the hours of exposure in each period, we obtain the following indication as to the average percent of fading per hour of exposure.

Exposure Period	Average Per Cent Fading Per Hour of Exposure		Ration of Machine Fading to Weather Fading	
	REU*	REW†	REU	REW
10 Days Weather	.082	.092	1	1
40 Hours National Carbon Unit	.154	.154	1.88	1.67
40 Hours Twin-Arc Weather-Ometer	.502	.502	6.12	5.46
40 Hours Fade-Ometer	.350	.350	4.27	3.80
20 Days Weather	.098	.114	1	1.
80 Hours National Carbon Unit	.134	.134	1.37	1.18
80 Hours Twin-Arc Weather-Ometer	.414	.414	4.22	3.63
80 Hours Fade-Ometer FDA-R	.229	.229	2.34	2.01
30 Days Weather	.092	.096	1	1
120 Hours National Carbon Unit	.136	.136	1.48	1.42
120 Hours Twin-Arc Weather-Ometer	.349	.349	3.79	3.64
120 Hours Fade-Ometer FDA-R	.182	.182	1.98	1.90
30 Days Weather	.092	.096	1	1
160 Hours National Carbon Unit	.116	.116	1.26	1.21
160 Hours Twin-Arc Weather-Ometer	.353	.353	3.84	3.68
160 Hours Fade-Ometer FDA-R	.161	.161	1.75	1.68

* REU—Loss in Reflectance of Exposed but unwashed samples.
† REW—Loss in Reflectance of Exposed but washed samples.

It is seen that the fading per hour of exposure remains relatively constant for the outdoor exposures over a 10, 20 and 30-day period. However, in the case of each of the accelerated fading units the average fading per hour exposure was maximum during the initial 40-hour period and progressively decreased in the 80, 120 and 160-hour periods. On the basis of hour for hour exposure in the various accelerated fading machines, the following ratio exists between the rate of fading in accelerated fade test units and the rate of fading in weather. These figures are based on the average ratio of machine fading to weather fading as shown in the previous sub-table.

Types of Exposures	Average Ratio of Weather Fading to Machine Fading		Average Ratio of Per Cent Fading of Accelerated Fade Test Units, Using the National Carbon Unit as a Basis for Comparison	
	REU	REW	REU	REW
Weather	1	1	...	...
National Carbon Unit	1.50	1.37	1	1
Twin Arc Weather-Ometer	4.50	4.10	3.00	3.00
Fade-Ometer FDA-R	2.58	2.35	1.72	1.72

Question No. 6—What has surface characteristics of the textile fabric to do with the fading inhibiting effect of precipitations on the fabric?

Although essentially of the same texture it was noted that some of the fabrics exposed during the investigation seemed to pick up a bit more dirt than others, with a resultant decrease in the amount of fading recorded both before and after washing. Evaluations of dirt were based upon washings of the samples in an aqueous solution containing ½ per cent Igepon T for one hour in an Atlas Launderometer at 100° F. A portion of the wash solution was introduced into a weighed centrifuge tube and extracted for five minutes. After decanting, the remaining dirt in the centrifuge tube was brought to a constant weight in a conditioning oven. It was felt that the amount of dirt measured would be for the most part proportional to the ability of the fabric surface to trap and hold the soot precipitation. This dirt, it was felt acted in two ways: (1) to filter actinic rays reaching the fabric and (2) to cover and hide the extent of fading actually incurred. In each case the spectral characteristics of the dirt precipitation were superimposed upon the fading function. Again, using extreme cases, samples of white materials were exposed for periods of 10, 20 and 30 days during June, 1944, in Philadelphia, and measured at designated intervals during the exposure period. The loss in reflectance in the white materials because of dirt deposited is pictured in Chart VIII. Here it is seen the materials, tile, wood, cotton, and wool facing each retain dirt in the stated order of smoothness of surfaces, with resultant losses in reflectance.

There also remained the question of how fading would proceed in a given location if the dirt factor were removed, or at least reduced considerably. Further exposures made in Philadelphia are reported in Chart IX to show fading caused by exposure with and without glass. There appears to be no consistent difference between the two methods after 10 days' exposure, but after 20 and 30 days exposure, the increase of fading of the glass covered samples is marked.

CONCLUSION

It can hardly be claimed that any startling discoveries have insued from the program reported on herein. The laboratory under the direction of Colonel Steadman has sought to establish for the materials procured by the Quartermaster Corps, basic yardsticks in the evaluation of color fastness. Answers have been provided for the questions as to what comprises average olive drab serge fading under weather exposure during the summer months, as to what relationship exists between exposure in accelerated fading units and natural weathering, how fading varies from location to location and from month to month during the summer period of 1943, and finally what variables affect to the greatest degree the loss in color occurring on serge fabrics. It is felt that the data presented may afford a rough basis for reducing the performance of commercial accelerated fading units to an absolute figure based on natural weather exposures—in this connection calibration factors such as are to be discussed at length this evening will be essential.

Appreciation is expressed for the cooperation of those agencies noted in table 1 for it was their assistance that made the work reported on herein, possible. Acknowledgment is had of the assistance afforded by Capt. E. Monroe, formerly O.I.C. of the project section, L. I. Weiner, N. Edelman, Miss M. Brandriff and the shade matchers of the depot laboratory.

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431597

A Proposed Method for the Calibration of CARBON ARC LAMPS Used for Testing and Grading Light Fastness*

C. A. SEIBERT
E. I. du Pont de Nemours & Co., Inc.

IN the Year Book[1] of the American Assotion of Textile Chemists & Colorists and in Commercial Standards CS59[2] are described methods for testing and grading the light fastness of colored textiles in terms of hours of exposure in a carbon arc lamp.

Fundamentally, these methods are identical; however, they are different in important detail. The A.A.T.C.C. method uses standards for direct comparison with test specimens for grading, whereas Commercial Standard CS59 uses some of these standards to calibrate the lamp. Neither method is completely satisfactory to industry.

The A.A.T.C.C. method states: (Classification of Fastness to Light. "The Fastness to Light of the color of a textile in an exposure test shall be classified according to the following scheme when the standard dyeings are used:

Class L0 Textiles which show a greater change in color than standard L1.

Class L1 Textiles which show no greater change in color than standard L1.

Class L2 Textiles which show no greater change in color than standard L2," etc.)

When tested by exposure in natural light and in lamps, colored textiles and the A.A.T.C.C. blue wool standards change in color as well as in strength. By the A.A.T.C.C. method of grading, it is required to compare color changes of yellows, reds, violets, greens, etc., with the color change in the blue standards and to judge how the quantities compare. The criticism of some in industry is that it is impossible to judge these differences with the degree of accuracy that is required for practical commercial use.

The Standing Committee of Commercial Standard CS59, which includes 25 persons representing all sections of the textile industry and the public, recognized this criticism and attempted to avoid or correct it by the use of some of the standards to calibrate the lamp.

The following is copied from Commercial Standard CS59-44, pages 21 and 22: (The apparatus shall be considered to be operating satisfactorily providing

standard sample L3 does not fade appreciably with 5 hours' exposure, but does fade appreciably with 10 hours' exposure;

standard sample L5 does not fade appreciably with 20 hours' exposure, but does fade appreciably with 40 hours' exposure;

standard sample L7 does not fade appreciably with 80 hours' exposure, but does fade appreciably with 160 hours' exposure.

55. Reporting color fastness to light.

55c. Class 2.—textiles which show no appreciable change in color after exposure to light in the apparatus for 20 hours shall be reported as having "Class 2" color fastness to light.)

The requirements for classes 1, 3, 4 and 5 are identically described, except that the hours of exposure are 10, 40, 80 and 160 or more, respectively.

There are two conditions in this system that can be changed to provide improved accuracy; however, one change will correct both. The terms, appreciable fade, for calibration of the lamp and appreciable change for classification are subject to variations in interpretation, regardless of the intended interpretation of the term as described in page 2 of the pamphlet from which the following is copied.

6. Interpretation of color fastness test results.

6b. A specimen shall be considered to pass a given test when there is no appreciable change in color and also when there is no appreciable staining of the white cloth attached to it. "Appreciable change" shall be understood to mean a change that is immediately noticeable in comparing the tested sample with the original; etc.

Commercial Standard CS59 uses the carbon arc lamp exclusively for testing and grading light fastness, whereas the A.A.T.C.C. method permits the use of the lamp, but prefers exposure in natural light.

The use of carbon arc lamps for testing and grading is established in industry. Industry is accustomed to describe light fastness requirements in specifications, in terms of hours of exposure in this lamp and in some Federal Specifications, light or weathering fastness requirements are described in terms of hours of exposure in the Atlas Weather-Ometer and/or in the National Carbon Company Accelerated Testing Unit lamp. These are both carbon arc lamps.

It is well known by many who use them and reported in technical literature that these lamps are not precision instruments and that the rate at which they cause color destruction (fading) varies rather widely in different lamps and in all lamps during the time that different trims of carbons burn. Theoretically, these inconsistencies should not influence accurate testing and grading when standards are used for direct comparisons. However that system is not entirely satisfactory for reasons that have been described. This situation has prompted much thought and work to find a system that will be free of, or correct the unsatisfactory conditions of both systems now used.

The following part of this report describes a system designed to measure daily the quantity of fading energy generated by the lamps. The means designated as Control, a piece of colored paper or cotton is exposed in the lamps for 20 hours or for the time a trim of carbons burn. It is then compared with a set of Standards which represent the Control after it has been exposed in a theoretical standard lamp for periods of 12-14-16-18-20-22-24-26-28 hours. The standards will be in the form of relatively permanent colored 1 inch square chips.

As an illustration for the use of the Control and Standards, we will assume that after 20 hours of exposure in the lamp under consideration, the Control appears like the Standard that illustrates the Control after it has been exposed for 20 hours in the Standard Lamp. This would demonstrate that for that 20-hour period, the lamp under consideration has performed like the Standard Lamp; therefore, all test samples in that lamp for the 20-hour period would be credited with having received 20 hours of exposure.

Now let us assume that the Control after 20 hours of exposure in the lamp under consideration, appears like the Control after exposure in the Standard Lamp for 14 hours. In this case, all test samples in that lamp for that 20-hour period

* Presented at meeting, Philadelphia Section, April 20, 1945.

would be credited with having received 14 hours of exposure instead of 20 hours. Similar corrections would be made for faster and slower lamps as required by a comparison of the Control with the Standards. It is believed that by this means, differences in fading rates can be compensated so that exposures in all lamps would give similar results for grading, provided the lamps were different in fading rates only, and not in quality of fading.

The idea of this system is not new at this time. Work to perfect it has been under way for several years and it is the subject of a paper for the Intersectional Contest by the New York Section of the A.A.T.C.C., reported in the *American Dyestuff Reporter*, volume 31, 1942, page 595. The contribution at this time, is a report of a survey to learn the average fading rate of a relatively large number of lamps, the selection of a suitable Control, a means to calculate from photometer measurements, the quantity of color change effected in fading lamp exposures, in a simple form that is in acceptable agreement with visual comparisons, and suggestions for means to place the system in practical use.

The first trials to find a Control were with the old A.A.T.C.C. light fastness standards. They were exposed for specified numbers of hours by members of the A.A.T.C.C. light fastness committee. Curves of these exposures were made in the General Electric Recording Spectrophotometer and calculations made of measurements at the points of least reflectance using Beers Law and conversion by the —Log T table. It was recognized that this system was designed for absorption and not reflectance measurements; however, its possible usefulness for reflectance measurements was considered worth trial. It was recognized that some approved mechanical means to supplement visual comparison was desirable, if not definitely required, to assure required accuracy. This need is recognized by those familiar with the subject and can be readily demonstrated. However, it requires a lengthy explanation with illustrations which can be omitted without detriment to the value of this report. The figures from the measurements calculated in percentage color change were inconsistent and varied widely with visual measurements.

When this condition, together with what it was desired to accomplish, was discussed with a physicist well informed about problems connected with the physical measurement and description of color, by the system described in the "Handbook of Colorimetry" by Professor Hardy and by what appeared a very complicated system of computations, he provided figures which were in acceptable agreement with visual comparisons. Discussion disclosed that the problem would be simplified by the use of colored specimens that change in strength only and not in color.

Further work disclosed that selected dyes, applied to nylon, which include Pontacyl Violet S4B, Colour Index 698, Pontacyl Fast Red AS, Colour Index 176 and Anthraquinone Blue SWB, a prototype of Alizarine Supra Blue A, on exposure to light, become progressingly weaker and are entirely destroyed, leaving the nylon in its original, nearly white color when the exposure is continued long enough. These three are mentioned because they exhibit other qualities that are required to be useful for the present purpose.

It was next learned that nylon colored with 0.3 per cent of its dry weight of the red, lost more than 40 per cent of its tinctorial strength when exposed for 20 hours in an FDA-R model Fade-Ometer and that this quantity of dye was completely absorbed by the nylon. This was a very valuable quality for two reasons. Nylon could be colored with 0.3, 0.27, 0.24, 0.18, 0.15, 0.12, 0.09, 0.06 and 0.03 per cent of the dye which represents strength reductions in steps of 10 per cent, and these could be used for visual comparison measurements with a degree of accuracy considered satisfactory. When nylon colored in accordance with this scheme is examined, it is observed that the differences between the 10, 20, 30, 40 and 50 per cent strength reductions appear less in degree than the differences between the 50, 60 and more percentage reductions in strength. Therefore, strength losses in excess of 50 per cent can be judged with more accuracy than strength losses which are in the range of less than 50 per cent.

Several yards of nylon were colored with 0.3 per cent and with lesser quantities of dye in steps of 10 per cent reductions. This was done three times. The dyed nylon was then compared visually and found in acceptable agreement with the known quantities of the dye used. Photometer measurements were also found to be within 5 per cent of theory.

Pieces of the nylon colored with 0.3 per cent of the dye were sent for exposure in about 20 different lamps. These exposures again very clearly demonstrated the differences between different lamps and in the individual lamps from day to day. In these exposures selected to include lamps known to represent the extremes in slow and fast rates, one lamp was found that was 2.5 times faster in rate than any other lamp. Perhaps more clearly described, in this one lamp between 6 and 8 hours of exposure caused as much strength loss as occurred in 20 hours of exposure in any of the other lamps. This was discouraging because it indicated a possible fault in this red nylon as a satisfactory measurement of fading rates. In more exposures this one lamp continued to show this condition. This prompted the thought that a lamp could conceivably be abnormal in some range of the visible spectrum and normal in some other ranges. This theory was supported by evidence already available, and it is known that both carbons and globes act independently to control conditions required to make the spectral character of the light that reaches the exposed samples similar to an average of natural light measured under some specific and selected condition. Variations in the carbons have from time to time been suspected. An investigation by a competent photochemist with no business connection with either the manufacturer or distributors of the carbons disclosed that the greatest variations between carbons could only possibly be responsible for a small fraction of the differences in rates between individual lamps.

The next consideration was for possible differences in the transmission character or quality of the globes. To learn the facts was considered beyond the scope of this investigation at this time, although work is already started to uncover information about the globes and their possible influence on the differences in fading rates between lamps. While this condition was only found in one lamp among about 40 in which exposures had been made at some time during previously completed work, it directed attention to the possible superior usefulness of a control that would absorb in photometer measurements over a wider range of the visible spectrum than the red. Naturally a properly selected grey color will do this. The next step was the selection of a suitable grey. Whereas up to this time we had been seeking to avoid the use of a specimen that changed color on exposure, the thought occurred that color changes could conceivably serve to detect differences in quality of fading.

Consideration for a suitable grey color, prompted the thought that the ideal selection would be a grey made from a combination of a yellow, a red and a blue dye which in the required proportions would fade at a uniform rate. It was the thought that if a lamp was abnormal, that condition would cause the three dyes to fade at different rates and thereby disclose its abnormal fading quality. At this time we are not certain that we can accomplish

TABLE NO. 1

Percentage Color Change of Experimental Controls Effected by 8 and 12 Hours of Exposure in 63 Lamps and by 20 Hours of Exposure in 67 Lamps

These Include 37 FDA-R, 20 FDA, 8 CV & FO Model Fade-Ometers and 3 National Carbon Co. XV Model Lamps

	On Hours	Red Gray-Paper-Green 8	12	20	Grey 8	12	20	Grey Cotton 8	12	20
Code	Lamp									
1	FDA-R	23	33	41	10	19	29	24	31	40
3	FDA-R	32	40	51	23	35	45	32	46	57
4	CV	26	35	47	14	24	37	16	23	36
5	FDA-R #1918	29	41	46	22	28	34	15	31	40
5	FDA-R #1910	25	39	45	22	25	36	24	31	36
5	FDA-R #1918	26	35	47	24	22	34	21	25	40
5	FDA-R #1938	25	36	43	17	21	32	20	25	34
6	CV	28	32	45		NOT			RETURNED	
7	FDA ?	27	33	46	17	16	25	21	21	44
8	FDA-R*	27	37	42	17	26	31	21	35	34
9†	FDA-R	34	39	56	32	36	49	30	30	46
10	FDA*	33	41	47	18	30	32	27	42	45
11	FDA-R*	39	44	50	21	24	37	27	37	44
12	FDA-R	16	28	37	21	30	35	22	37	46
14	CV	31	38	44	16	19	25	17	27	35
14	CV*	26	33	47	16	21	28	19	35	42
15	FDA-R*	34	43	56	22	27	37	26	43	55
17	FDA-R*	36	41	57	24	33	43	35	41	52
17	FDA		32	43	12	18	25	26	31	41
18	FDA-R	32	42	52	27	33	42	26	36	45
19	FDA-R	35	43	54	26	30	40	31	36	48
			REPEAT	49			38			48
20	FDA-R	30	36	46	14	18	28	24	28	42
21	FDA-R #1811	24	34	44	13	16	22	24	21	37
21	FDA #1375	29	37	40	10	17	30	22	28	36
21	FDA #1564	27	33	44	19	17	27	19	25	34
22	FDA-R	32	43	48	20	23	26	29	31	39
23	FDA-R	24	28	39	12	22	26	22	26	31
24	FDA	33	43	48	22	33	34	29	39	41
25†	FDA-R*	32	42	44	22	23	27	32	32	39
26	FDA*	35	44	57	23	29	39	25	36	47
27†	FDA-?	33	37	46	20	23	31	22	29	35
29	FDA-R	25	34	47	21	24	31	35	36	48
29†	FDA-R #2	35	42	50	18	25	35	30	40	41
30	FDA	29	36	47	17	22	30	28	29	36
31†	CV	33	39	47	20	26	32	32	42	44
32	FDA	30	35	43	15	17	25	17	29	31
32	FDA-R	34	41	45	19	23	34	16	30	39
33†	FDA-R	40	52	61	22	32	40	33	44	50
33†	FDA	30	42	52	16	24	34	26	36	44
33†	FDA-R*	32	45	55	22	30	41	25	36	48
34	CV	36	44	55	23	22	34	27	37	46
35	FDA-R	25	33	45	16	17	29	20	35	39
36	FDA	25	33	41	15	22	34	27	29	34
37	FDA-R	32	42	49	26	29	36	28	29	46
39	FDA	25	34	45	19	23	28	29	27	41
40	FDA-R	33	47	56	28	36	46	29	40	52
41	FDA-R	35	42	55	24	28	40	28	39	47
42	FDA-R	23	28	38	8	13	23	22	24	32
43	FO ?	29	41	52	33	34	47	33	43	47
45	FDA-R	36	41	51	26	33	38	31	35	42
46	FDA ?	37	44	52	28	31	42	36	41	54
47†	FDA	30	41	48	18	30	37	25	32	36
48	NCC XV	30	43	51	19	24	35	26	40	55
49	FDA #1	33	39	45	19	25	31	29	30	34
49	FDA-R #2	27	38	42	18	24	37	22	32	38
49	FDA-R #3	37	45	53	30	36	50	30	38	48
49	FDA #4	38	43	53	25	30	50	30	37	42
49	FDA #5	34	45	51	23	30	42	28	36	40
50	FDA-R	31	38	43	21	25	35	32	38	43
51	FDA-R	33	43	54	19	35	44	30	37	50
51	NCC XV	28	33	42	12	16	26	21	27	38
52	FDA-R	32	32	46	20	23	37	26	32	40
53†	FDA-R			47			35			39
53†	FDA			48			32			39
53	NCC XV			61			39			57
55	FDA-R	36	44	54	26	32	38	35	40	47
55	FDA	32	38	47	18	20	30	26	33	39
	AVERAGES %	30	39	48	20	25	35	26	33	42
	Number of lamps	63	64	68	63	63	67	63	63	67
	Deviations low (7)	23	30	40	11	17	24	17	23	33
	Deviations high	37	45	58	29	35	47	34	43	54

† The unexposed paper samples were not returned for use as controls and therefore a control measurement was taken from a suitable part of an exposed sample.
* Operated on DC current. All others either unreported, or reported as operated on AC current.

that purpose through this means. We believe much more work is required to uncover pertinent information and it is intended to follow that line of investigation and report on it as some later date. However, for various reasons, we selected a reddish grey and greenish grey colored paper and a greenish grey cotton sample after considerable experimentation.

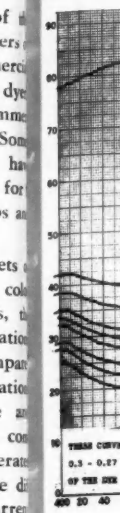
The next step was to learn the average fading rate of a representative number of fading lamps used in industry for testing and grading light fastness. Pieces of these grey samples were sent to 56 persons concerned with testing and grading. These included the members of the A.A.T.C.C. and A.S.T.M. light fastness committees, the optical properties committee of the Technical Association of the Pulp and Paper Industry, the members of the Standing Committee of Commercial Standard CS59 and 19 commercial dyers and finishers, dye manufacturers, commercial testing laboratories and others. Some to whom these samples were sent, have more than one lamp and exposures for 8 and 12 hours were made in 63 lamps and for 20 hours in 67 lamps.

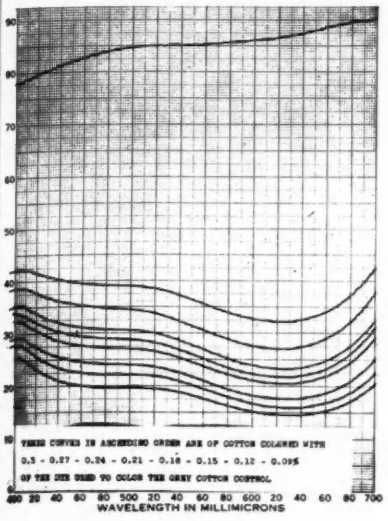
Table No. 1 consisting of 3 sheets of tabulations describes the percentage color changes effected in these exposures, the averages and the high and low deviations from the averages. Table No. 2 compares the averages and low and high deviations considered in respect to the type and model of the lamps. Table No. 3 compares the different type lamps operated on AC current and Table No. 4 the different type lamps operated on DC current.

Many dyers and finishers have established standards for grading to fulfill classification requirements described in Commercial Standard CS59. These or many of them were established on exposures made in FDA model Fade-Ometers, therefore this new proposed system for measuring and compensating differences between lamps should be established on the basis of FDA model averages so as not to disturb these industry established standards. Fortunately, in the present survey the averages of all the lamps compared with the averages of the different models show differences of less than 5 per cent, therefore, the averages of all the lamps can be used for the present proposed system without disturbing already established industry standards.

The next step is to prove that the means used to measure and describe the changes effected in the exposures, is logically sound and acceptable.

Graph A are photometer curves of unbleached cotton colored with different quantities of the dye used to color the grey cotton Control. The lowest curve is the grey cotton Control and the other curves in ascending order represent cotton colored with 90-80-70-60-50-40-30 per cent of the quantity of the dye used to color the Control. It will be observed that while the spaces between these curves are not uniform, the curves maintain an approximate uniform relation across the scale. If we use the —log T table for conversion of measurements made at any point across the scale they will not be in agreement with visual comparisons, however, if we use the K/s table for conversion, we find the differences represented by the figures, in acceptable agreement with visual comparisons. The K/s formula used for the figures in all the tables that





Graph A

accompany this report, is described in an appended memorandum.

Table 8 illustrates conversion calculations by the K/s table of measurements on Graph A. The fact that the percentage differences in table 8 are not in precise agreement with the differences in the quantities of the dye used, is explained by the fact that the cotton did not absorb all of the dye from the baths in which it was colored. Cotton rarely does in practical dyeing. In this instance as in others of a similar character, the individual cotton samples did not absorb identical percentages of all the dye present.

In Table 1 is described the percentage color changes effected in the exposures made in the individual lamps, calculated from the K/s table for conversion. All of the samples that were made in the lamps by the cooperators designated Code 1 to 10, 11 to 20, 21 to 30, 31 to 40, 41 to 50 and 51 to 55 were examined in this order of grouping without any reference to Table 1, and placed in the order of most to least color change. This required many comparisons. However, three different persons had very little difficulty in separating the individual exposures to be in agreement with the order of the figures in Table 1, when the differences in the table are 5 per cent or more. When the total percentage color change in the table is less than 20 per cent, the order of arrangement by visual comparisons is not consistently in agreement with the order of the figures in the table. This is because these differences are relatively small visually and visually smaller than indicated by the differences in the figures in the table.

If the exposed samples of the grey cotton are compared with the grey cotton samples illustrated in Graph A and a table prepared of percentage color changes from these visual comparisons, the visual comparison table will describe the percentage color changes as less than the percentage

TABLE NO. 2

Average Percentage Color Change of Experimental Controls Effected by Exposure for 8-12-20 Hours in 57 Fade-Ometers. These Include 31 FDA-R, 18 FDA and 8 CV or FO Models. And Lamps Operated on Both AC and DC Current

On Hours	Red Grey-Paper-Green Grey 8	12	20	8	12	20	Grey Cotton 8	12	20
Averages	30	38	47	20	25	34	26	33	41
Deviations Low (6)	23	30	40	12	15	25	17	24	33
Deviations High	39	45	56	29	35	48	34	42	51
IN 31 FDA-R MODEL FADE-OMETERS									
Averages	30	38	47	21	26	35	26	33	42
Deviations Low (5)	22	30	40	13	17	25	18	25	34
Deviations High	36	45	56	29	35	46	33	40	51
IN 18 FDA MODEL FADE-OMETERS									
Averages	31	38	47	19	25	33	26	32	39
Deviations Low (3)	26	33	41	13	17	26	19	25	33
Deviations High	36	44	56	22	30	39	31	41	47
IN 8 CV OR FO MODEL FADE-OMETERS									
Averages	30	37	48	17	21	29	22	30	37
Deviations Low (2)	26	33	45	15	20	26	17	25	36
Deviations High	34	42	53	21	25	35	32	42	46
***IN 3 NATIONAL CARBON COMPANY XV MODEL LAMPS**									
	28	33	42	12	16	26	21	27	38
	30	43	51	19	24	35	26	40	55
			61			39			57

* In 2 lamps, exposures for 8-12 and 20 hours were made, whereas in the third lamp, only 20 hour exposures were made.

The figures following the word "Low" (6) (5) (3) (2) are the number of lamps used to compute the averages for both the low and high deviations in that tabulation.

TABLE NO. 3

Average Percentage Color Change of Experimental Controls Effected by Exposure for 8-12-20 Hours in Lamps Operated on AC* Current

On Hours	Red Grey-Paper-Green Grey 8	12	20	8	12	20	Grey Cotton 8	12	20
IN 47 FADE-OMETERS OPERATED ON AC CURRENT									
Averages	30	38	47	20	25	34	26	33	41
Deviations Low (6)	23	30	40	12	16	25	18	24	33
Deviations High	37	45	57	28	35	47	33	41	51
IN 26 FDA-R MODEL FADE-OMETERS OPERATED ON AC CURRENT									
Averages	29	38	47	21	26	35	26	33	42
Deviations Low (5)	22	31	40	13	17	25	18	25	34
Deviations High	35	44	55	29	35	46	33	39	49
IN 14 FDA MODEL FADE-OMETERS OPERATED ON AC CURRENT									
Averages	30	38	46	18	23	32	25	30	38
Deviations Low (3)	26	33	43	13	17	26	19	25	34
Deviations High	35	44	51	23	31	43	29	37	42
IN 7 CV OR FO MODEL FADE-OMETERS OPERATED ON AC CURRENT									
Averages	30	38	48	21	25	34	26	35	42
Deviations Low (2)	27	34	44	15	21	26	17	25	36
Deviations High	34	42	53	27	28	42	32	42	46
IN 3 NATIONAL CARBON COMPANY XV MODEL LAMPS OPERATED ON AC CURRENT									
	28	33	42	12	16	26	21	27	38
	30	43	51	19	24	35	26	40	55
			61			39			57

* In some instances the information about current, etc., was not furnished. In the absence of that information these tabulations are based on the assumption that the lamps were operated on AC current.

TABLE NO. 4

Average Percentage Color Change of Experimental Controls Effected by Exposure for 8-12-20 Hours in Lamps Operated on DC Current

On Hours	Red Grey-Paper-Green Grey 8	12	20	8	12	20	Grey Cotton 8	12	20
IN 8 LAMPS: 4 FDA-R, 3 FDA AND 1 CV MODEL FADE-OMETER									
Averages	33	41	50	20	27	34	26	37	45
IN 4 FDA-R MODEL FADE-OMETERS									
Averages	33	41	48	21	25	33	26	36	43
IN 3 FDA MODEL FADE-OMETERS									
Averages	35	42	54	22	31	38	29	40	48
IN 1 CV MODEL FADE-OMETER									
	26	33	47	16	21	28	19	35	42

Spectrophotometer measurements made at 580 millimicrons on the reddish grey paper, at 600 on the greenish grey paper and at 620 on the grey cotton. Calculations by the K/s formula which was designed for use in this work by Dr. Edwin R. Laughlin of the Technical Laboratory of the Du Pont Company and which is described by him as part of this report. By means of the K/s formula it is possible to determine from reflectance measurements the per cent of actual color destruction resulting from exposure to light.

TABLE NO. 5

Percentage Color Change Effected by Fade-Ometer Exposures on the No. 2 A.A.T.C.C. New Blue Wool Standard Intended to Serve for 2½ and 5 Hours of Exposure in Grading Light Fastness

Exposures by Code	Lamp Model	When Made	EXPOSURE HOURS 2.5	5	10	20	40	80	160
45	FDA-R	10/44	14	19	23	35	50	64	77
56	FDA-R	11/44		21	27	35	49	63	
3	FDA-R	10/44		14	27	34	46	64	76
29	FDA-R	11/44		15	18	28	41	54	70
49	FDA #1	11/44		15	22	29	39	51	64
	FDA-R #2			15	23	29	47	54	75
	FDA-R #3			14	25	32	46	56	77
	FDA #4			15	22	28	38	51	69
	FDA #5			15	22	24	35	48	68
18	FDA-R			18	26	34	45	61	77
53	FDA	10/44		21	26	34	34	55	68
	FDA	11/44	12	19	26	34	41	55	69
	FDA-R	11/44	17	19	21	37	46	62	76
17	FDA-R	11/44		17	34	45	58	73	84
47	FDA	11/44		15	23	31	41	49	55
	AVERAGES		14	17	24	33	44	57	72

These figures are calculations by the K/s formula from spectrophotometric measurements at 610 millimicrons.

TABLE NO. 6

Percentage Color Change Effected by Fade-Ometer Exposures on the No. 3 A.A.T.C.C. New Blue Wool Standard Intended to Serve for 5 and 10 Hours of Exposure in Grading Light Fastness

Exposures by Code	Lamp Model	When Made	EXPOSURE HOURS 2.5	5	10	20	40	80	160
45	FDA-R	10/44	9	10	12	19	32	43	56
56	FDA-R	11/44			16	21	29	42	55
3	FDA-R	10/44		9	14	19	31	45	55
29	FDA-R	11/44		3	6	15	26	36	48
49	FDA #1	11/44		6	12	15	21	34	51
	FDA-R #2			9	15	17	29	36	55
	FDA-R #3			6	15	19	29	39	57
	FDA #4			6	9	15	26	34	49
	FDA #5			6	12	15	17	34	49
18	FDA-R			12	15	21	29	45	56
53	FDA	10/44		6	15	21	21	38	49
	FDA	11/44	2	6	12	19	25	38	47
	FDA-R	11/44	6	12	17	23	31	45	55
17	FDA-R	11/44		15	19	29	40	51	64
47	FDA	11/44		6	9	17	23	34	45
	AVERAGES		6	8	13	19	27	40	53

These figures are calculations by the K/s formula from spectrophotometric measurements at 610 millimicrons.

TABLE NO. 7

Percentage Color Change Effected by Fade-Ometer Exposures on the No. 4 A.A.T.C.C. New Blue Wool Standard Intended to Serve for 10 and 20 Hours of Exposure for Grading Light Fastness

Exposures by Code	Lamp Model	When Made	EXPOSURE HOURS 2.5	5	10	20	40	80	160
45	FDA-R	10/44	7	8	9	18	25	34	41
56	FDA-R	11/44				15	22	31	41
3	FDA-R	10/44		7	9	15	20	32	43
29	FDA-R	11/44		4	7	10	13	25	38
49	FDA #1	11/44		7	8	10	18	27	37
	FDA-R #2			7	10	13	20	27	41
	FDA-R #3			7	10	13	20	27	41
	FDA #4			7	8	10	13	20	34
	FDA #5			4	7	10	15	25	38
18	FDA-R			7	10	13	20	31	44
53	FDA	10/44		7	10	13	15	27	35
	FDA	11/44	4	7	8	15	16	29	34
	FDA-R	11/44	4	7	10	15	20	32	41
17	FDA-R	11/44		10	13	22	31	41	48
47	FDA	11/44		7	10	13	18	22	37
	AVERAGES		5	7	9	14	19	29	40

These figures are calculations by the K/s formula from spectrophotometric measurements at 610 millimicrons.

TABLE NO. 8

Calculations by the K/s Formula from Spectrophotometric Measurements of the Grey Cotton Control, and of Cotton Colored with Lesser Percentages of the Dye Than Was Used to Color the Control Dyeing

Percentage of Dye Used	Quantity of Dye on the Fiber Expressed in Percentage of the Quantity of the Dye on the Control Dyeing and Calculated from Measurements Made at millimicrons 640	620	550	490
CONTROL—0.3%	100	100	100	100%
0.30%	100	100	100	100%
0.27%	89*	88	88	84%
0.24%	76	79	79	72%
0.21%	62	63	66	60%
0.18%	56	58	58	53%
0.15%	50	48	48	48%
0.12%	38	40	42	37%
0.09%	28	30	31	29%

* If all the dye used had been absorbed by and uniformly distributed on and in the cotton and the system of measurements and calculations was absolutely accurate, the figures would be 100-90-80-70-60-50-40-30%. However, it is well known that cotton does not completely exhaust all the dye in any normal dyeing operation.

color changes in Table 1.

When the percentages in Table 1 are less than 50 per cent, the percentages in the visual comparison scale will be about 20 per cent less and consistently so in visual comparison tables made by the three persons who cooperated in this part of the work. When the grey cotton is exposed in the Fade-Ometer until it shows changes between 50 and 80 per cent in photometer measurement calculations, the differences between photometer and visual figures decreases as the figures for the percentage color change increase. If the visual comparisons are made under an ordinary electric light, the differences between photometer and visual comparison figures is only about one-half the differences in natural light. Some part of this difference in the visual comparisons, is because in exposures the grey cotton becomes noticeably duller which influences the strength appearance.

These differences do not disturb either the usefulness or the accuracy of the photometer measurement calculations because the standards for compensating differences in fading rates, can be established entirely independent of photometer measurement calculations as will become apparent later in this report. However, that calculations by the K/s table from photometer measurements are reliably useful, is indicated by the figures for the averages in Table 10. This is a comparison of a blue colored wool and a gray colored cotton made in three different lamp models daily for 31 days. These figures illustrate the average percentage color change in the CV model Fade-Ometer as 38 per cent for the gray cotton and 28 per cent for the blue wool.

In the FDA model Fade-Ometer the figures are 30 and 22 per cent. If we return to our school days and solve a problem in proportions which reads 38 is to 28 as 30 is to X we find the answer is 22.

Now if we use the slide rule we will find that the figure 30 for the blue wool in the FDA-R model Fade-Ometer is less than 2 per cent from what it should be. Now if we consider the proportion 38 and 30, we find 28 and 22 in order and the figure 30 in the 43:30 combination, 4 per cent off.

We have been using the gray cotton control in 4 lamps for at least eight months and the No. 2 A.A.T.C.C. blue wool standard since it became available, about four months. The gray cotton is prepared in sufficient quantity to serve six lamps for a month and during the time we have been using it we have prepared at least eight separate lots. Calculations from photo-

TABLE NO. 9

Comparison of Percentage Color Change Effected by Exposure in an FDA-R Model Fadeometer with Exposure in Sunlight in Florida

Hours of Exposure	Reddish Grey Paper FDA-R Lamp	Reddish Grey Paper Florida Sunlight	Greenish Grey Paper FDA-R Lamp	Greenish Grey Paper Florida Sunlight	Grey Cotton FDA-R Lamp	Grey Cotton Florida Sunlight
2		17		7		9
4		25		9		16
6		31		14		15
	* X		* X		* X	
8	28–37	37	24–19	13	28–34	24
10		43		16		33
12	37–47	45	30–29	17	36–39	35
14		48		20		36
16	41–49	53	32–34	23	43–39	40
18		55		25		47
20	57–52	58	32–36	25	48–40	49
22		61		28		55
24	62–57	64	39–41	27	57–52	57
26		68		31		61
28	65–63	68	40–43	33	60–57	62
30		70		36		64

* The figures in this column are of exposures made under conditions whereby carbons and globes were changed at 8 hour intervals, whereas, the figures in this column X represent exposures when the carbons and globes were changed at 20 hour intervals.

Calculations are by the K/s formula from spectrophotometric measurements at 580 millimicrons for the reddish grey paper, at 600 for the greenish grey paper and at 620 for the grey cotton.

TABLE NO. 10

Percentage Color Change of the Grey Cotton Control and of the A.A.T.C.C. No. 2 Blue Wool Standard Effected Daily for 30 Days by Exposure in a CV, in a FDA and in a FDA-R Model Fadeometer

Date 1945 March	CV LAMP Exposure Hours	CV LAMP Percentage Change Grey	CV LAMP Percentage Change Blue	FDA LAMP Exposure Hours	FDA LAMP Percentage Change Grey	FDA LAMP Percentage Change Blue	FDA-R LAMP Exposure Hours	FDA-R LAMP Percentage Change Grey	FDA-R LAMP Percentage Change Blue
1	20	42	31	20	32	24	20	43	28
2	20	39	31	20	30	23	20	43	28
3	20	35	32	20	25	23	20	43	34
4	17	37	32	17	23	25	17	34	31
5	20	33	28	20	27	23	20	39	28
6	20	41	30	20	24	24	20	37	30
7	20	36	28	20	29	20	20	42	30
8	20	36	28	20	32	20	20	39	28
9	20	38	26	20	26	20	20	43	30
10	20	36	32	20	30	23	20	41	30
11	10	22	21	20	30	27	20	44	34
12	18	35	23	20	35	23	20	49	31
13	22	39	31	20	38	26	20	41	30
14	20	41	31	20	39	26	20	44	30
15	20	40	29	20	34	22	20	41	29
16	20	38	28	20	27	20	20	39	30
17	20	40	27	17	20	18	20	46	31
18	20	42	29	18	24	18	20	46	29
19	20	39	26	20	23	16	20	41	29
20	20	42	29	17	19	14	20	45	29
21	20	36	27	20	33	20	20	46	28
22	20	39	26	20	28	16	20	45	28
23	20	41	26	20	30	18	20	46	28
24	20	37	22	20	26	16	20	44	29
25	20	35	24	18	20	18	20	42	28
26	20	42	28	20	29	24	20	44	31
27	20	36	30	20	33	26	20	45	34
28	20	37	28	20	32	24	20	41	31
29	20	41	28	20	27	16	17	41	28
30	20	37	24	20	33	22	14	39	24
31	20	29	26	20	24	20	20	42	32
Averages for 20 hour exposures ONLY		38	28		30	22		43	30

The figures are calculations by the K/s formula from spectrophotometric measurements made at 620 millimicrons for the grey cotton and at 610 for the blue wool.

meter measurements indicate the greatest differences between the eight separate dyed lots is in the order of 5 per cent and visual comparisons are in similar order.

While the A.A.T.C.C. No. 2 blue wool standard may also be used as the control we prefer the gray cotton because it shows greater strength losses. The blue may have the possible defect described for the red nylon and it is much more difficult to prepare, being a blend of two wools colored with two different dyes which cannot be applied in combination to wool piece goods to produce consistent results. We have been using the A.A.T.C.C. blue wool standards 2, 3 and 4 for about six weeks to gather data on variations in fading rates in one Weathering Lamp. If the system proposed in this report for measuring and compensating differences in the fading rates in fading lamps is acceptable for practical adoption, it is intended to do the work required to recommend a similar system for Weathering Lamps.

The exposures made on the reddish gray paper which is colored with a combination of a yellow, a red and a blue cotton dye indicates that it may be possible to detect abnormal qualities of fading in carbon arc lamps by the use of a Control colored with a suitable combination of dyes, however, the reddish gray paper used in the present experiments is not considered suitable for that purpose. More work is planned to explore that possibility which it is anticipated will require a relatively long time to complete.

In the present work the exposures of the reddish gray paper samples are not in agreement in respect to the color change that has occurred. The exposed samples can be divided into two groups.

In one group the exposed samples have an orange color and in the other they are outstandingly bluer in color. The outstandingly orange colored group were made in the lamps by the cooperators designated by the following code numbers: 1-6-7-12-14 both lamps, 15-17 the FDA lamp, 19-20-21 the FDA-R lamp No. 1811, 22-23-24-25-33 the FDA-R lamp operated on DC current, 42 and 51, and to a lesser degree, but still outstanding, 40-48-49 FDA lamps No. 4 and No. 5. The sunlight exposures made in Florida under glass, have the orange color appearance. (Table No. 9.)

At first we suspected that the orange colored exposures were due to higher than normal temperatures, however, exposures at 160°F. do not consistently produce that color effect. We do not at this time have an explanation for these differences and mention it only to indicate the need for further study.

There is much more information in the tables and graphs that merits consideration, such as the fact that in the lamp assigned the code number 9 the greenish gray paper shows approximately as much change as the other two samples, whereas, in the general averages the greenish gray paper shows appreciably less percentage change.

However, discussion of these abnormalities and other interesting information in the tables and graphs is not definitely pertinent to the establishment of the standards for compensating differences in fading rates.

It is already mentioned and illustrated by the graphs that accompany this report that similar percentage strength differences in excess of 50 per cent appear greater than when the total is less than 50 per cent. For this and other reasons, we prefer the gray cotton for the Control and Standards. It shows greater percentage changes in identical hours of exposure than the greenish gray paper and while the reddish gray paper shows slightly greater percentage changes than the gray cotton, much greater difficulty is anticipated in coloring the paper than the

cotton.

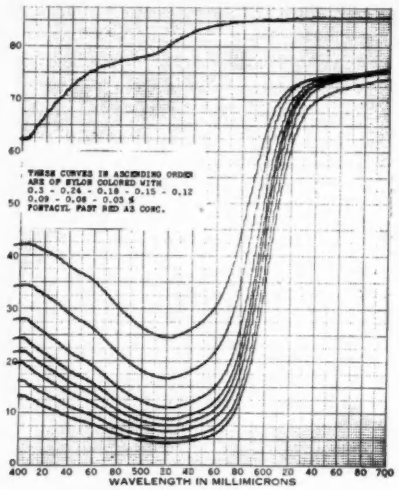
There are two methods that may be used for the establishment of the Standards. Pieces of the gray cotton can be exposed in the Standard Lamp at the Bureau of Standards until they show the identical percentage color change as the average for 20 hours described in Table 1. That will require the use of the photometer measurements and calculations system used to establish that average. When the hours of time required in that lamp to reproduce the average percentage color change is established, other exposures in the lamp for 10, 20, 30 and 40 per cent less time and for 10, 20, 30 and 40 per cent more time can be made and the exact appearance of these exposed samples reproduced in the form of two-inch square chips relatively permanently colored like the chips in the Munsell Book of Color. It is estimated that cards containing the ten different chips required, together with a brief printed description for their use, can be prepared at a cost of about $2.50 per card. It is obvious that the 10, 20, 30 and 40 per cent less and more time exposures would represent 18, 16, 14, 12 and 22, 24, 26 and 28 hours of exposure and the figures representing the differences between the lamps in Table 1 are within this range.

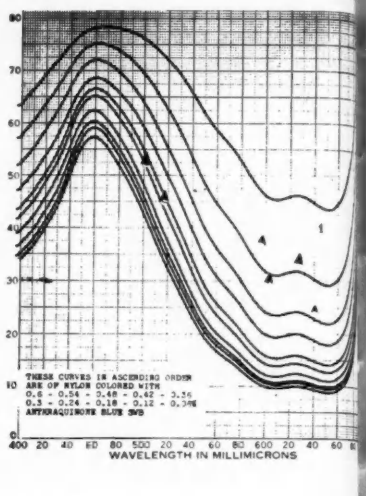
The other method that may be used to establish the Standards to permit compensating differences in fading rates between lamps is arithmetical.

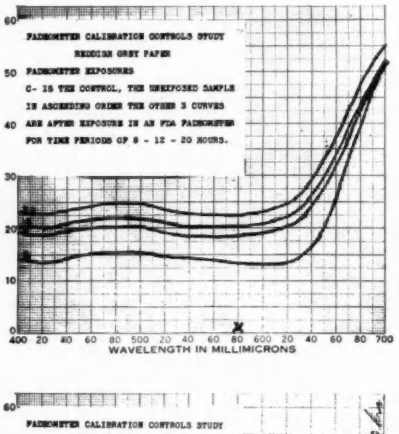
The percentage calculations would be made from photometer measurements at 550 or 620 millimicrons and conversion by the K/s table.

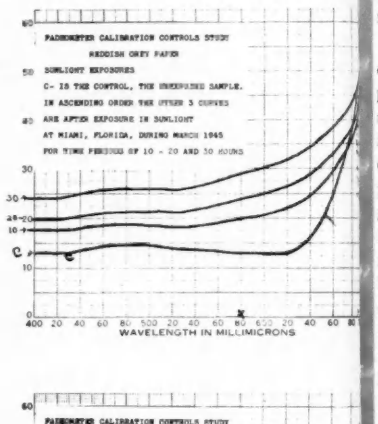
This method would serve to compensate differences for the time that a trim of carbons serve, but it would not serve for lesser time periods such as for 2, 4, 6, 8 and 10 hours. A supplementary Control and Standards to serve for calibrating the lamps for these shorter time periods are required. As illustrations: for grading class 0, and class 1 in Commercial Standard CS59, which are based on 10 hours of exposure, and for grading classes LO to L4 in the A.A.T.C.C. scale, which are based on 10 or less hours of exposure.

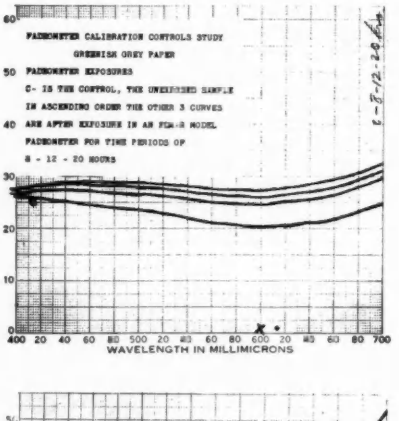
If samples to fulfill a 20-hour requirement are being tested, the first 20 hours of exposure may only be equivalent to 16 or 18 hours in the Standard Lamp. The exposure must then be continued for the time required to complete the equivalent of 20 hours exposure in the Standard Lamp. The gray cotton control proposed to serve for the full time a trim of carbons burn, is not sufficiently sensitive to serve for between 2 and 10 hours. Many trials have failed to find one Control to serve for both time period measurements.

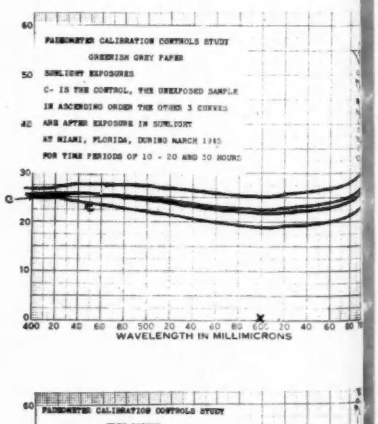

THESE CURVES IN ASCENDING ORDER
ARE OF NYLON COLORED WITH
0.3 - 0.26 - 0.18 - 0.15 - 0.12
0.09 - 0.06 - 0.03 %
FONTACIL PAST RED AS CONC.
WAVELENGTH IN MILLIMICRONS

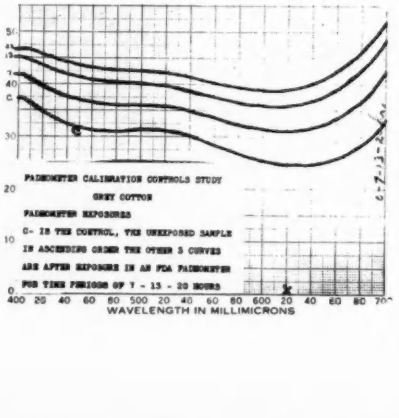

THESE CURVES IN ASCENDING ORDER
ARE OF NYLON COLORED WITH
0.6 - 0.54 - 0.48 - 0.42 - 0.36
0.3 - 0.24 - 0.18 - 0.12 - 0.06%
ANTHRAQUINONE BLUE SWG
WAVELENGTH IN MILLIMICRONS

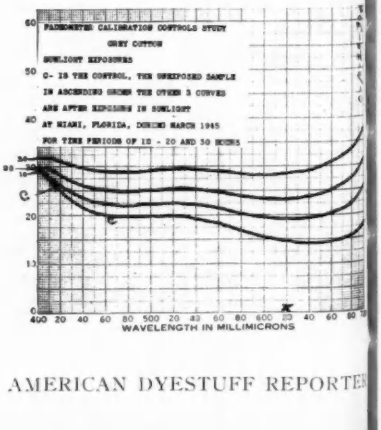

FADEOMETER CALIBRATION CONTROLS STUDY
REDDISH GREY PAPER
FADEOMETER EXPOSURES
C- IS THE CONTROL, THE UNEXPOSED SAMPLE
IN ASCENDING ORDER THE OTHER 3 CURVES
ARE AFTER EXPOSURE IN AN FDA FADEOMETER
FOR TIME PERIODS OF 8 - 12 - 20 HOURS.
WAVELENGTH IN MILLIMICRONS


FADEOMETER CALIBRATION CONTROLS STUDY
REDDISH GREY PAPER
SUNLIGHT EXPOSURES
C- IS THE CONTROL, THE UNEXPOSED SAMPLE.
IN ASCENDING ORDER THE OTHER 3 CURVES
ARE AFTER EXPOSURE IN SUNLIGHT
AT MIAMI, FLORIDA, DURING MARCH 1945
FOR TIME PERIODS OF 10 - 20 AND 30 HOURS
WAVELENGTH IN MILLIMICRONS


FADEOMETER CALIBRATION CONTROLS STUDY
GREENISH GREY PAPER
FADEOMETER EXPOSURES
C- IS THE CONTROL, THE UNEXPOSED SAMPLE
IN ASCENDING ORDER THE OTHER 3 CURVES
ARE AFTER EXPOSURE IN AN FDA-R MODEL
FADEOMETER FOR TIME PERIODS OF
8 - 12 - 20 HOURS
WAVELENGTH IN MILLIMICRONS


FADEOMETER CALIBRATION CONTROLS STUDY
GREENISH GREY PAPER
SUNLIGHT EXPOSURES
C- IS THE CONTROL, THE UNEXPOSED SAMPLE
IN ASCENDING ORDER THE OTHER 3 CURVES
ARE AFTER EXPOSURE IN SUNLIGHT
AT MIAMI, FLORIDA, DURING MARCH 1945
FOR TIME PERIODS OF 10 - 20 AND 30 HOURS
WAVELENGTH IN MILLIMICRONS


FADEOMETER CALIBRATION CONTROLS STUDY
GREY COTTON
FADEOMETER EXPOSURES
C- IS THE CONTROL, THE UNEXPOSED SAMPLE
IN ASCENDING ORDER THE OTHER 3 CURVES
ARE AFTER EXPOSURE IN AN FDA FADEOMETER
FOR TIME PERIODS OF 7 - 13 - 20 HOURS
WAVELENGTH IN MILLIMICRONS


FADEOMETER CALIBRATION CONTROLS STUDY
GREY COTTON
SUNLIGHT EXPOSURES
C- IS THE CONTROL, THE UNEXPOSED SAMPLE
IN ASCENDING ORDER THE OTHER 3 CURVES
ARE AFTER EXPOSURE IN SUNLIGHT
AT MIAMI, FLORIDA, DURING MARCH 1945
FOR TIME PERIODS OF 10 - 20 AND 30 HOURS
WAVELENGTH IN MILLIMICRONS

To establish the Control and Standards for the shorter time periods is a relatively simple problem, and the work is well underway and will be reported in the near future.

It is believed that this proposed system for calibrating carbon arc lamps used for testing and grading light fastness is logically sound and practically useful and that through the use of this means exposures in all lamps would result in similar gradations and that exposures in any lamp could be correlated with exposures in any other lamp.

The author of this report will welcome comment and criticism of its content from anyone and a statement from anyone who will use the proposed method. If a sufficient number will use it for practical trials to warrant the expense, cards of the Standards will be prepared for distribution at cost.

As of possible interest to a better understanding of this report, graphs of photometer curves of the red and blue nylon mentioned in the earlier part are included as are graphs of photometer curves of Fade-Ometer and sunlight exposures of the reddish gray and greenish gray paper and gray cotton. In the sunlight exposures, the hours of exposure represent sunlight hours, not daylight hours). Table 9 is included to illustrate comparative percentage color changes effected by identical hours of exposure in an FDA-R model FadeOmeter and in Florida sunlight during the month of March 1945. The FDA-R Fade-Ometer used for these exposures appears to be in fading rate within 5 per cent of the averages for the 8, 12 and 20 hour exposures of the gray cotton in Table 1. The sunlight exposures were made in Miami, Florida, by the South Florida Test Service.

It is clearly evident from the work that was done for this report and a rather intimate study of problems concerned with the use of carbon arc lamps for testing and grading light fastness during a period of at least 15 years, that rotating the samples around the arc during testing produces a much greater degree of uniformity between identical samples exposed at different times than is obtained when the samples are in a stationary position in respect to the arc.

Some may consider the proposed method for calibration of the lamps too complicated for practical use; however, it does correct one very well recognized unsatisfactory condition in the present use of the lamps for testing and grading light fastness and the method is not more complicated than some test methods accepted for practical use to determine the physical properties of textiles to fulfill some specific requirements.

Calibration of the lamps is not all that is required to have a system for testing and grading light fastness, technically satisfactory. There still remains the problem of establishing tolerances for permissible degrees of color change in grading that can be described in more precise terms than "appreciable change" and "more and less than." There are at least two different methods that may be used to correct this condition. One is: in tables 5, 6 and 7 are described the average degree of color change that has been effected by exposure in 15 lamps on the A.A.T.C.C. new blue wool standards #2, #3 and #4.

Number 2 is intended to serve for between 2.5 and 5 hours, and the average change is 17 per cent after 5 hours of exposure. Number 3 is intended to serve for between 5 and 10 hours, and the average change for 10 hours is 13 per cent. Number 4 is intended to serve for between 10 and 20 hours, and the average change for 20 hours is 14 per cent. Why not establish as the maximum permissible degree of color change, 15 or 20 per cent measured photometrically at the point of least reflectance between 400 and 700 millimicrons and calculated from the conversion tables for the K/s formula.

This method could be predicated on the acceptance of the K/s formula as a satisfactory means of measurement by the Committee on Color of the A.A.T.C.C. or if desired by the Intersociety Color Council.

Like many new proposals, this suggestion appears awesome, but it is not; it is no more complicated than the addition of a column of figures.

The other method is to establish that "to fulfill a requirement for any specified numbers of hours of exposure in a fading lamp, the test specimen shall show no perceptible color change in 40 per cent less time of exposure." As an illustration: to fulfill Class 1, CS59 requirement, the test sample shall show no perceptible change after 6 hours of exposure and similarly for Class 2, no change in 12 hours; for Class 3, no change in 24 hours; for Class 4, no change in 48 hours, etc. If desired, for Class 4 and higher Class gradings the time for no perceptible change could be reduced to 30 or 20 per cent.

Both methods establish conditions that eliminate differences in opinions in respect to interpretation of descriptive terms.

Both methods as here described can be modified and/or clarified in detail. The object at this time is to suggest fundamental methods to eliminate conditions that are recognized as unsatisfactory, technically.

The author expresses thanks to all who cooperated by making exposures and especially to Dr. Edwin R. Laughlin of the Technical Laboratory of the DuPont Company for his very valuable contribution in the form of the K/s formula and table for conversion.

REFERENCES

[1] Year Book of the American Association of Textile Chemists and Colorists is available from its secretary, Dr. Harold C. Chapin, Lowell Textile Institute, Lowell, Mass.

[2] U. S. Department of Commerce, National Bureau of Standards, Textiles-Testing and Reporting, fourth edition, Commercial Standard CS59-44, available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C. for 10 cents a copy.

* *

THE CALCULATION OF DYE ON THE FIBER FROM SPECTRAL REFLECTIVITY MEASUREMENTS USING THE K/S FORMULA

The equation of Kubelka and Munk[1] quantitatively defines monochromatic reflectivity R_{OO}:

$$R_{OO} = 1 + (K/S) - [(K/S)^2 + 2(K/S)]^{1/2}$$

where K = absorption coefficient as fraction of the incident energy lost by absorption per unit thickness of material

and S = scattering coefficient or fraction of incident energy lost due to scattering per unit thickness of material

The assumptions made in the derivation of this equation are:

(1) The medium is homogeneous and sufficiently thick to be opaque.

(2) Reflectance is determined for completely diffuse illumination.

When the above equation which pertains to monochromatic light of some arbitrary wavelength unless otherwise specified is solved for the ratio of K/S, the result is:

$$K/S = \frac{(1-R_{OO})^2}{2R_{OO}}$$

Nolan[2] extended this equation to media containing several components and in the case of dyed fibrous materials assumed that the dye and fiber absorbed and scattered the light independently of one another and further that the absorption coefficient for a dye was proportional to its concentration. The fact that observed values and those calculated theoretically checked within an average of 0.6 per cent lent substantial credence to the validity of his assumptions.

Foote[3] extended this work further in dealing with dyed paper handsheets, and while he was able to show that Nolan's assumptions did not hold at all concentrations of dye, the absorption coefficient was directly proportional to dye concentration in light and medium shades but not in very heavy shades. In heavier dye concentrations the log of absorption coefficient was directly proportional to the log of concentration.

Since the scattering coefficient S of a dyed fibrous composition is practically independent of the dye for all but very full shades, it follows that the ratio K/S as determined from monochromatic reflectivity is proportional to concentration of dye except in very full shades.

The proof of this statement has been experimentally verified on a number of dyed textile materials. Data on ten nylon samples dyed with Fast Red AS in concentrations ranging from .03 per cent to 0.3 per cent (100 per cent exhaustion of dye) in which the reflectivity at the wavelength of maximum absorption varied between 27 per cent and 4 per cent, gave a perfectly straight line when K/S was plotted against concentration. The same was true for other acid dyes applied to nylon.

Also, wool crepe was dyed with .01 per cent to 2.0 per cent Wool Blue BL using a method which gave complete color exhaustion in all but the very full shades. The reflectivity at the wavelength of maximum absorption for the 13 samples varied from 29 per cent to 1.07 per cent. K/S was plotted versus dye concentration as was log K/S versus log dye concentration. In both cases a straight line resulted providing the reflectance at the wavelength of maximum absorption was 2 per cent or more. When the reflectance is as low as 1.6 per cent the point is not far off the straight line, but when lower the points are considerably far off. It is recognized the accuracy of the spectrophotometer is questionable in this extremely low range.

However, by selecting a wavelength other than that of maximum absorption so the values of R_{∞} would be 5 per cent or higher, then the K/S values plotted against concentration gave a straight line relationship even for the very full shades of Wool Blue BL.

This tends to indicate that the K/S method is applicable to most dyed fabrics. It is, of course, necessary in dealing with pastel shades to correct for the K/S value of the undyed material, just as it is essential in full shades to select a wavelength where the reflectance is greater than say 5 per cent.

[1] Kubelka, P. and Munk, F., "Z. Tech. Physik" 12:593-601 (1931).
[2] Nolan, P., "Paper Trade J." 105, No. 14:42-5 (Sept. 30, 1937).
[3] Foote, W. J., "Tech. Assoc. Papers" 22:397 (1939).

* * *

COMMENTS ON THE USE OF K/S METHOD

By E. R. Laughlin

The preceding remarks perhaps require a little further explanation.

Two data tables follow which illustrate in one case calculations from reflectance data on nylon dyed with Pontacyl Fast Red AS Conc., using various concentrations of dye and a method of dyeing which insures virtually complete exhaustion of the dyestuff, and in the other case wool dyed with Pontacyl Wool Blue BL Conc. 200 per cent.

Dyeing on Wool Using Pontacyl Wool Blue BL Conc. 200%

% Dye	Reflectance*	K/S Dyed Wool	K/S Dye	K/S Dye / % Dye	% Deviation from Average
0.50	1.55	31.30	31.24	62.5	4.6
0.35	2.10	22.82	22.75	65.1	0.6
0.30	2.40	19.845	19.78	66.0	0.8
0.20	3.45	13.513	13.448	67.3	2.8
0.13	5.20	8.641	8.576	65.9	0.6
0.08	8.3	5.065	5.000	62.5	4.6
0.04	14.4	2.544	2.479	62.0	5.3
0.02	21.0	1.486	1.421	71.0	8.4
				Avg. 65.5	Avg. 3.5%

* Reflectance measurements made at 590 millimicrons.
Undyed wool: reflectance at 590 millimicrons 69.8 K/S .065

Dyeings on Nylon Using Pontacyl Fast Red AS Conc.

% Dye	Reflectance*	K/S Dyed Nylon	K/S Dye	K/S Dye / % Dye	% Deviation from Average
0.30	4.72	9.617	9.604	32.0	5.6
0.27	5.10	8.829	8.816	32.6	3.8
0.24	5.54	8.057	8.044	33.5	1.2
0.21	5.90	7.513	7.500	35.7	5.3
0.18	6.94	6.239	6.226	34.5	1.8
0.15	8.60	4.857	4.844	32.3	4.7
0.12	9.46	4.333	4.320	35.9	5.9
0.09	11.90	3.261	3.248	36.1	6.5
0.06	17.55	1.937	1.924	32.0	5.6
0.03	26.04	1.050	1.037	34.6	2.1
				Avg. 33.9	Avg. 4.25%

* Reflectance measurements made at 520 millimicrons (point of maximum absorption).
Undyed nylon: reflectance at 520 millimicrons 85.28 K/S .013

In both cases, the dyeings were measured spectrophotometrically at the wave length of maximum absorption. It is essential in accumulating data of this type to take several readings on each sample so that a true average reflectance value may be obtained.

In each of the two tables, the column at the left indicates the per cent of dye calculated on the weight of the fiber, and since the exhausts in all cases were clear this indicates the percentage of dye on the fiber. The third column in each case is the K/S value for the dyed fiber determined by means of tables. It is important to determine also the reflectance of the undyed fiber at the wave length under consideration so that the K/S value for the fiber may be subtracted from the K/S value of the dyed fiber to give in column four the K/S value for the dye.

Column five shows the K/S value for the dye divided by the per cent dye, and it will be noted that this value is reasonably constant and that the average deviation from this value is approximately 4 per cent.

It is particularly important in making reflectance measurements of dyed fabrics to fold the sample to a sufficient thickness that further increase in the thickness does not alter the reflectance value.

It is recognized that there are limitations to the K/S method, particularly in evaluating very heavy dyeings where the reflectance values are extremely low. Experience has shown that on cotton and nylon reflectance values should be at least 5 per cent or higher if there is to be a linear relationship between the K/S value for the dye and dye concentration. The data table on wool dyed with Pontacyl Wool Blue BL Conc. 200 per cent shows that the linear relationship holds for reflectance values as low as 1.55 per cent but this represents an unusual rather than an average condition, and in general it is desirable to have the reflectance values within a 5 per cent to 20 per cent range for optimum results.

This method is unquestionably subject to considerable improvement, and it is hoped that in the future it will be possible to modify it so as to obtain still greater accuracy; nevertheless, experience has shown that most dyed fabrics and dyed paper may be examined spectrophotometrically and the amount of dye present calculated with an average error of less than 5 per cent using, of course, suitably prepared controls.

In examining a dyed material before and after fading where the fading causes loss of color depth with minimum change in hue, the K/S method appears ideally suited to calculating the per cent of color destruction with a degree of accuracy not disproportionate to that obtainable in the other operations involved in making such a test.

MEETINGS, NORTHERN NEW ENGLAND SECTION

MAY MEETING:—

May 19, 1944. Dinner and meeting at the Andover Country Club, Andover, Mass. Christian F. Klebsattel spoke on "What Is Ahead for Textiles." Harold W. Leitch, Chairman of the Nominating Committee, made his report and the election of Sectional officers for the 1944-1945 season was held.

OCTOBER MEETING:—

October 20, 1944. Dinner and meeting at the Hotel Manger, Boston, Mass. Lt. Col. John H. Talbott, Medical Corps, A. U. S., Commanding Officer and Director of Research at the Climatic Research Laboratory in Lawrence, Mass., gave a talk on "Clothing and Equipment for the Combat Soldier." Col. Talbott also presented an exhibit of soldiers equipped and clothed with the latest ideas along this subject.

NOVEMBER MEETING:—

November 17, 1944. Dinner and meeting at the Hotel Manger, Boston, Mass. Professor Edward R. Schwarz, of Massachusetts Institute of Technology, and President of the Massachusetts Safety Council, presented a paper on "Textile Safety Engineering."

JANUARY MEETING:—

January 26, 1945. Dinner and meeting at the Hotel Manger, Boston, Mass. William D. Appel, President of the A.A.T.C.C., spoke on the "Activities of the Association." Walter J. Hamburger, of Fabrics Research, Inc., read the Northern New England Section's Intersectional Contest Prize Paper, "Physical Properties of Nylon."

MARCH MEETING:—

March 16, 1945. Dinner and meeting at the Hotel Manger, Boston, Mass. Daniel Knowland, Geigy Company, Inc., and a prominent member of the New York Section, presented a paper, "Idiosyncrasies in Color Matching by Young and Old."

Respectfully submitted
Azel W. Mack, *Secretary*

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MEMBERSHIP APPLICATIONS

SENIOR

Bror E. Anderson—Chemist, Johnson & Johnson, Chicago, Ill. Sponsors: A. J. Olson, A. G. Alexander.

Roy S. Carey—Tech. Repres., National Aniline Div., Allied Chemical & Dye Corp., Philadelphia, Pa. Sponsors: R. Robertson, V. Jacobsen.

S. Jack Davis—Research Chemist, Callaway Institute, Inc., La Grange, Ga. Sponsors: W. B. Griffin, F. S. Perkerson.

Carl Finocchio—New Process Dyeing & Finishing Co., Paterson, N. J. Sponsors: L. J. Roos, L. W. Craft.

Percival C. Gregory, Jr.—Asst. General Manager, Union Bleachery, Greenville, S. C. Sponsors: C. N. Rabold, E. S. Tillinghast.

William F. Harty—President and Treasurer, Pawtucket Dyeing & Bleaching Co., Inc., Pawtucket, R. I. Sponsors: E. J. Allard, R. Bayer.

Peter G. Morin—Supt. of Dyeing & Bleaching, American Thread Co., Willimantic, Conn. Sponsors: H. D. Corkum, A. Veevers.

Frederick E. Petke—Associate Chemical Director, Hilton Davis Chemical Co. Div., Sterling Drug Co., Cincinnati, Ohio. Sponsors: J. P. Bauer, H. X. deRedon.

Victor S. Salvin—Research Chemist, Celanese Corp. of America, Cumberland, Md. Sponsors: G. C. Ward, D. Y. Miller.

W. Kyle Ward, Jr.—Head Cotton Fiber Research Div., South. Reg. Research Lab., New Orleans, La. Sponsors: R. K. Worner, J. D. Dean.

Edward W. Yates—Managing Partner, Yates Bleachery Co., Flintstone, Ga. Sponsors: J. Anderson, G. H. Boyd.

Alfred M. Zimmerman—Foreman and Chemist, Jaunty Fabrics Corp., Scranton, Pa. Sponsors: A. Malick, H. G. Scull.

JUNIOR

Elayne May Keane—Textile Technologist, Good Housekeeping Inst., New York, N. Y. Sponsors: F. Stutz, W. E. Coughlin.

John W. Moore—Chemical Engineer, National Cotton Council of America, Austin, Texas. Sponsors: M. T. Barnhill, O. G. Edwards.

Edward A. Murray—Research Assoc., National Cotton Council of America, Austin, Texas. Sponsors: M. T. Barnhill, O. G. Edwards.

ASSOCIATE

Richard R. Fisher—Secretary and Treasurer, Columbia Woolen Mills, Columbia City, Ind. Sponsors: V. Hartquist, L. Hoehn, Jr.

John O. Kjome—Tech. Repres., Van Waters & Rogers, Inc., Portland, Ore. Sponsors: T. M. Marshall, E. B. Brearley.

Max H. E. Moerel—Chemical Advisor, Netherlands Economic Mission, New York, N. Y.

Charles P. Tully—Maintenance Supervisor, The Drybak Corp., Binghamton, N. Y.

(Other applications appear on page P264)

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COMING MEETINGS, RHODE ISLAND SECTION

THE Rhode Island Section will hold meetings on the following dates during the 1945-46 season: October 26, 1945, November 23, 1945, January 25, 1946, February 22, 1946, March 22, 1946 and April 26, 1946.

COMING MEETINGS, NEW YORK SECTION

THE New York Section will hold meetings on the following dates at the Downtown Athletic Club, 19 West Street, New York City, during the 1945-46 season: October 11, 1945, December 7, 1945, February 1, 1946, March 15, 1946 and May 3, 1946.

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SECTIONAL COMMITTEE MEETING, SOUTHEASTERN SECTION

MEMBERS of the Southeastern Section of A.A.T.C.C. have been unable to hold regular meetings so far this year. The Sectional Committee of this section held a business meeting at the Ansley Hotel, Atlanta, Ga., June 2, 1945.

The committee voted favorably on a motion to hold a regular meeting in October or November, provided O. G. Edwards, Chairman, felt that travel conditions warranted.

A. K. Haynes, Chairman of our By-Laws Committee, read the proposed By-Laws for our section, and a copy will be sent to each member for their vote of approval or disapproval.

M. T. Barnhill, Chairman of our Intersectional Contest Paper Committee, reported that satisfactory progress is being made in the preparation of our paper.

Sectional Committee members present were: M. T. Barnhill, James C. Farrow, A. K. Haynes, J. W. Swiney, J. M. Youngblood.

Respectfully submitted,
W. B. GRIFFIN, *Secretary*.

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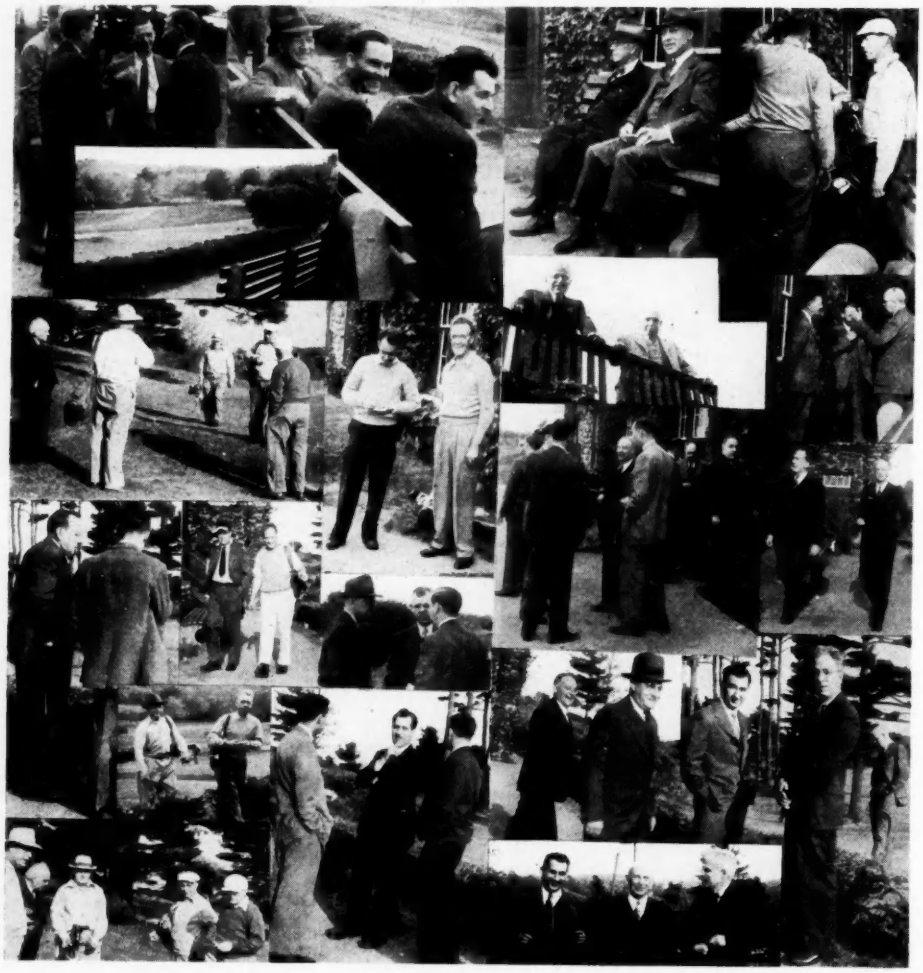
NEW COLORFASTNESS STANDARDS AVAILABLE

STANDARD dyeings for classifying the fastness to light of textiles have just been issued by the A.A.T.C.C. These standard dyeings, which are available in a set of seven fabric samples of different degrees of light fastness, were prepared by an entirely different method from that used for earlier standards. The principle involved is that wool fibers dyed with a fugitive dye and fibers dyed with an extremely fast dye can be mixed in different proportions so as to give almost any degree of light fastness, with only two dyes and two dyeings being used. The dyes employed were Erio Chrome Azurole B for the fugitive dye, and Indigosol or Algosol Blue AGG for the fast dye. Standard L2, the most fugitive, is a straight 0.4 per cent dyeing of Erio Chrome Azurole B. Standard L8, the fastest, is made from a blend containing 5 per cent of fibers dyed with Erio Chrome Azurole B and 95 per cent dyed with Indigosol or Algosol Blue AGG (3 per cent dyeing).



Photos by Dr. H. C. Chapin

AMONG THOSE PRESENT AT THE MEETING OF THE NORTHERN NEW ENGLAND SECTION AT THE ANDOVER COUNTRY CLUB ON MAY 25th, 1945.

The standard dyeings are suitable for use in determining the fastness to light of all types of dyed or printed yarns and fabrics and in testing the fastness of dyestuffs for application to textiles. They are recommended particularly for testing colorfastness to light by the tentative standard method of the A.A.T.C.C. The seven standard dyeings in the form of swatches approximately 5x18 inches in size are supplied in a folder on which are printed complete instructions for their use in making fastness tests by exposure to sunlight, in fading lamps, weathering lamps, etc. The standards can be obtained from Dr. Harold C. Chapin, Secretary, American Association of Textile Chemists & Colorists, Lowell Textile Institute, Lowell, Mass., at a nominal price of $2 per set.

Lapel buttons, at $1.50 each, may be purchased, by members in good standing, from the Secretary.

CALENDAR OF COMING EVENTS

Meetings, Council and Research Committee, Hotel Commodore, New York City, October 5, 1945. Chairmen of Sub-Committees who wish to hold meetings on October 4th at the Hotel Commodore should notify Dr. Louis A. Olney.

Meeting, New York Section, Downtown Athletic Club, New York City, October 11, 1945.

Meeting, Rhode Island Section, October 26, 1945.